MAY 1945
NO. 134

ASTM Bulletin

NEWS—Annual Meeting, Technical Committees, District Activities.

PAPERS—Steam Gage; Radiography, Plastics, Neutralization Number, Electrical Conductivity.

American Society for Testing Materials

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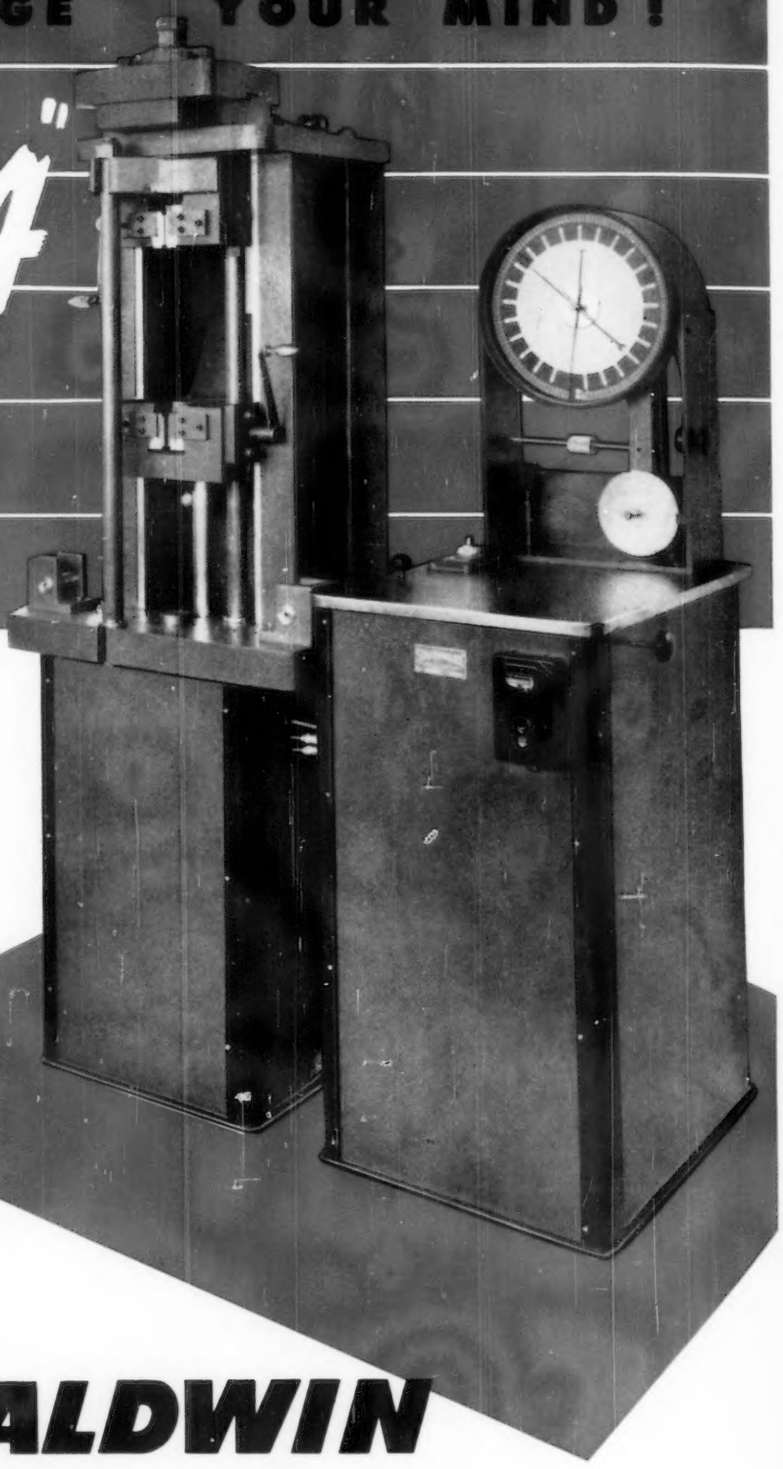

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ASTM BULLETIN

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MAY—1945
No. 134

ASTM BULLETIN

"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

TELEPHONE—PENnypacker 3545 R. E. Hess, Editor R. J. Painter, Associate Editor CABLE ADDRESS—TESTING

Number 134 May 1945

One-Day Annual Meeting in New York City, June 27

Change in Plans Due to Travel Restrictions; New Officers Will Be Announced; President's Address; Actions on By-laws, Charter, Standards

INSTEAD of the five-day annual meeting of the Society originally scheduled for Buffalo, N. Y., late in June, the 1945 Annual Meeting will be held as a one-day affair, getting under way at 2 p.m. in the Hotel Pennsylvania, New York, on June 27. Announcement of this change in the plans was sent to each member of the Society through Circular No. 263, dated May 1. This pointed out that a business meeting would be held to permit receiving reports of standing committees where actions on formal standards are required, and furthermore, to enable changes in the By-laws and Charter to be initiated.

The Executive Committee's report that is to be presented details actions proposed in the By-laws and which will necessitate modifications in the Charter, but in addition there is being mailed to each member on May 25 a full statement explaining the changes and giving them in detail by showing the proposed By-laws in parallel with the current By-laws.

ACTIONS ON STANDARDS

Despite the fact that the annual meeting will not be of the kind normally held, this will in no way affect progress being made by a great many of the Society's standing technical committees. Most of these groups will present reports and a procedure is planned at the business meeting so that recommendations involving formal standards—either the adoption of specifications as standard or revisions in existing standards—will be carried through. Any actions on formal standards must be approved at the annual meeting and subsequently referred to Society letter ballot. Actions on tentative specifications—proposed new tentatives, revisions, etc., will not be taken at the annual meeting, but will be referred to the Society's Committee E-10 on Standards.

Most of the reports and many of the technical papers that would normally have been presented are being preprinted, and members received a Preprint Request Blank early in May. While it is important that comments and discussion of any of the *reports* should be received well in advance of June 27, written discussion of the *technical papers* need not be submitted until later in the year, but preferably before November 1. It is hoped that many of the members and others interested will submit written discussion of the papers. Some of these papers may be presented at meetings sponsored by District Committees in various industrial centers.

COMMITTEE MEETINGS

While there may be meetings on and around June 27 of some of the Society's groups, for the most part these committees have been convening during recent weeks at various localities, some of these meetings being covered in news accounts in the BULLETIN. Where it is essential that the larger committees get together appeals will be made to the War Committee on Conventions so that these can meet if the business is considered essential.

PRESIDENT'S ADDRESS—GUEST SPEAKER AT DINNER

Under the auspices of the New York District Committee, a dinner will be arranged for the evening of June 27, following the A.S.T.M. business meeting, to feature the annual address of the retiring President, P. H. Bates, and it is planned to have a guest speaker cover a topic relating to some interesting phase of the use of materials. Further details of the dinner will be sent to all members in the New York area so that reservations can be made.

While President Bates at this writing has not selected the official title of his Address, members can look forward to an interesting discussion. During the year he has included a message in each issue of the BULLETIN that has been thought-provoking, timely and very ably expressed. Those who have read the articles or members who will refer to his 1940 Edgar Marburg Lecture will need no further hint that the 1945 President's Address will be well worth hearing and reading.

ABSTRACTS OF PAPERS AND REPORTS

Although the 1945 preprint request blank has been distributed to all members enabling them to request material that is preprinted, it is thought desirable to include in this BULLETIN (see back pages) abstracts of most of the reports and papers that normally would have comprised the technical features of the annual meeting sessions. This material will give members a conception of activities in the technical committees and the material on papers will give some idea of the

For synopses of 1945 reports and papers, turn to page 83.

major points covered by the various authors. In normal years, this material would have been arranged in the form of a provisional program with the sessions and times indicated, but this year with a one-day business meeting in effect, the material has been segregated only according to general materials fields involved.

Marburg Lecture and Dudley Medal

Although presentation of the 1945 Edgar Marburg Lecture will not take place until the 1946 meeting which it is hoped can be a full A.S.T.M. meeting, announcement is made of the selection by the Marburg Lecture Committee of an outstanding authority in the field of protective and decorative coatings, namely, Dr. J. J. Mattiello, Vice-President, Hilo Varnish Corp., Brooklyn, N. Y. Widely known for his work in this field and author of many papers, reports, and a monumental volume on protective and decorative coatings, his subject will be "Protective Organic Coatings as Engineering Materials." Active in many phases of war work he is affiliated with the Polytechnic Institute of Brooklyn, and is active in the work of various societies, in particular the Federation of Paint and Varnish Production Clubs. More information about the Lecture and the Lecturer will be forthcoming at a later date.

Dudley Medal.—The Committee on Award of the Charles B. Dudley Medal, consisting of J. H. Foote, *Chairman*, Commonwealth and Southern Corp.; Robert W. Orr, RCA Victor Division, Radio Corporation of America; and Roderick B. Young, Hydro-Electric Power Commission of Ontario, after a very rigorous examination of eligible technical papers presented during 1944, selected as a paper "of outstanding merit which constitutes an original contribution on research in engineering materials," the one on "Creep Characteristics of Plastics" by William N. Findley, Assistant Professor of Theoretical and Applied Mechanics, College of Engineering, University of Illinois, to receive the 1945 Medal. The paper was presented in the Symposium on Plastics held under the auspices of the Philadelphia District Committee in February, 1944. The time and place at which this award will be made will be announced, with the possibility that the function may be a feature of a meeting sponsored by one of the District Committees.

A.S.T.M. Activities in Ultimate Consumer Goods Field

Announcement was made in the March issue of the Bulletin of the authorization of a new Administrative Committee on Ultimate Consumer Goods in recognition of the greater emphasis that is being placed on ultimate consumer goods standardization in the work of the Society's standing committees and of the ever-increasing demand for standards in this field. This Administrative Committee has now been appointed to consist of the following members:

H. J. Ball, *chairman*, Lowell Textile Institute
A. G. Ashcroft, Alexander Smith & Sons Carpet Co.
A. L. Brassell, United States Testing Co.
Arthur W. Carpenter, The B. F. Goodrich Co.
Jules Labarthe, Mellon Institute of Industrial Research
G. C. MacDonald, Montgomery Ward and Co.
H. H. Morgan, Robert W. Hunt Co.

Standing, from left to right; A. L. Brassell, Arthur W. Carpenter, R. E. Hess, A. G. Ashcroft; seated, H. J. Ball, Jules Labarthe, G. C. MacDonald, H. H. Morgan.

The demand for standard specifications and methods of test applicable to ultimate consumer goods and for knowledge of materials for such use has been growing rapidly in recent years and this has been reflected in the work of a number of the Society's committees. There are, however, essential differences between industrial standards and those intended for ultimate consumer goods. Industrial specifications, for example, in general are written for the use of purchasers who know how to interpret the properties set up and who usually have inspection and testing facilities, whereas specifications for ultimate consumer goods may need to have different protection clauses and be written along somewhat different lines. There may be industrial and consumer specifications covering basically the same product, but the uses, tests, and background information will differ. The Administrative Committee is now giving consideration to the form and content of ultimate consumer goods standards in so far as they may differ from industrial standards including any special clauses that may be required. These will be developed in cooperation with the committees of the Society that are concerned with the ultimate consumer field.

It is intended that the Society's standardization work on ultimate consumer goods shall deal with only such goods as will permit of definition, test data, and test limitations that can be measured by engineering methods and that the work be based upon sound engineering principles. More factual knowledge will be required concerning the wants of consumers and more basic data on use values than are now available and attention will be given to means for securing this information.

Administrative Committee on Simulated Service Testing Personnel Announced

IN THE March BULLETIN we reported the appointment by the Executive Committee of a new Administrative Committee on Simulated Service Testing to be headed by L. L. Wyman, Research Metallurgist, Research Laboratory, General Electric Co., Schenectady, N. Y. This committee held its organization meeting at A.S.T.M. Headquarters on April 18. At that time the title given above, Simulated Service Testing, was formally adopted to describe its activities, this being further clarified by the original recommendation to the Executive Committee as reported in the March BULLETIN that the work of the committee would be to undertake the study, development, and standardization of methods of test of simple or composite materials in actual or simulated service conditions and environment, in so far as performance has a bearing on the properties of the material. It is understood that this may involve the testing of processed parts under such conditions.

The membership of the committee as appointed by President Bates is as follows:

L. L. Wyman, Chairman.
H. O. Boyvey, Chief of Development Labs., Consolidated Vultee Aircraft Corp., Vultee Field, Calif.
J. M. Frankland, Chief of Structural Test, Chance Vought Aircraft Div., Stratford, Conn.
D. E. Parsons, Chief, Masonry Construction Section, National Bureau of Standards, Washington, D. C.
R. E. Peterson, Manager, Mechanics Div., Westinghouse Electric Corp., East Pittsburgh, Pa.
S. B. Ritchie, Colonel, Ordnance Dept., U. S. Army, Washington, D. C.
R. L. Templin, Assistant Director of Research and Chief Engineer of Tests, Aluminum Company of America, New Kensington, Pa.
E. W. Upham, Chief Metallurgist, Chrysler Corp., Detroit, Mich.

All members of the committee were present except Mr. Boyvey who was unable to attend and was represented by B. C. Bromberg, Consolidated Vultee Aircraft Corp., Allentown, Pa., and Colonel Ritchie who was represented by E. L. Hollady, Office of the Chief of Ordnance, U. S. Army, Washington, D. C. Carter S. Cole of the A.S.T.M. staff serves as *ex-officio* secretary.

The committee will be administrative in nature and has very broad powers. Its function is not to do testing but to see that it gets done. When the committee decides that work should be done in a certain field it will make recommendations to existing committees to undertake the work if it comes within the scope of our present committee structure. If it is outside the scope of our present committee structures and the committee feels that the work should be done by A.S.T.M. it will recommend to the Executive Committee that a committee be established to cover the field.

The committee agreed on a tentative classification of types of testing that might be considered and on which recommendations could be made. These would fall into four general classes:

1. Prediction of performance in service by tests of fundamental material properties.
2. Prediction of performance in service by approximate simulation of service conditions.
3. Establishment of orders of merit—spot type test.
4. Research type on the relationship of fundamental material factors to service performance. (Correlation.)

Going into further detail the committee outlined in tentative form a number of specific types of test which it felt should be reviewed. Some of these were discussed at some length at this preliminary meeting. Full discussion of others was postponed to future meetings. Among these types of test which the committee will consider are the following:

Standing, from left to right: C. S. Cole, R. L. Templin, E. L. Hollady, B. C. Bromberg; seated, L. L. Wyman, R. E. Peterson, D. E. Parsons, E. W. Upham, J. M. Frankland. Insert upper left, H. O. Boyvey. An excellent photograph of Col. S. B. Ritchie appeared in the October BULLETIN in connection with the presentation of the Ordnance Distinguished Service Award.

1. Fatigue
2. Impact
3. Wear
4. Seizing and Gauling
5. Fretting (Seizing Corrosion)
6. Erosion
7. Erosion-Corrosion
8. Hardness
9. Creep
10. Rupture
11. Creep-Rupture
12. Corrosion
13. Stress - Corrosion
14. Multiaxial Stress
15. Compatibility
16. Environment
17. High Altitude Effect
18. Protective Coatings
19. Forming Characteristics
20. Elongation and Its Significance
21. Stress-Strain Diagrams
22. Vibration Testing
23. Tests of Springs
24. Tests of Hydraulic Packing
25. Flexure
26. Pressure Vessels
27. Fire Resistance
28. Load (life) Tests of Building Construction

The subject of fatigue testing and the present work of the Society's Research Committee on Fatigue of Metals were reviewed at some length. It was noted that some years ago there had been discussion on the establishment of a committee on impact, but due to war conditions this has not been set up. The Administrative Committee will review this matter and make recommendations thereon.

It is evident that part of the work of the committee will be to point out to existing committees of the Society the need here and there for a broader outlook on methods of test and interpretation and evaluation of test methods. Even in the preliminary review the committee concluded that there are many places in the Society where work of this kind can be encouraged.

When it comes to the correlation of material test with service performance, the work will involve correlation of A.S.T.M. and that of such other societies such as The American Society of Mechanical Engineers, the Society of Automotive Engineers, and the recently established Society for Experimental Stress Analysis. The committee expects to meet again within the next month or two and as its work takes definite form in the shape of recommendations that are of interest to Society members, news thereof will be given in future issues of the BULLETIN.

Recent Actions on Standards

Two of the standing committees, D-12 on Soaps and Other Detergents, and D-20 on Plastics, have sponsored actions recently approved by the Standards Committee, the items being as follows:

Tentative Method of Chemical Analysis of Soaps Containing Synthetic Detergents (D 820–45 T)

Revised Tentative Definitions of Terms Relating to Soaps and Other Detergents (D 459–45 T)

Tentative Revision of the Standard Methods of Sampling and Chemical Analysis of Soaps and Soap Products (D 460–44)

Tentative Specifications for Cast Allyl Plastic Sheets, Rods, Tubes, and Shapes (D 819–45 T)

Revised Tentative Method of Test for Heat Distortion of Temperature of Plastics (D 648–45 T)

Revised Tentative Method of Test for Colorfastness of Plastics to Light (D 620–45 T)

In addition, important recommendations have come through from the Joint A.W.S.-A.S.T.M. Committee on Filler Metal which were approved by the American Welding Society on April 19, and by the A.S.T.M. Standards Committee on May 19. These will be of widespread interest to all those concerned with iron and steel arc-welding electrodes, most of which fall in the mild steel or low-alloy types. Some details of the recommendations follow.

Perhaps the most important action of the joint committee was the decision to publish the Guide to A.W.S.-A.S.T.M. Classification of Iron and Steel Arc Welding Electrodes. This has been in preparation for many months and covers materials detailed in the Specifications for Iron and Steel Arc-Welding Electrodes (A 233). The Guide explains the significance of various specifications for electrodes, not only iron and steel, but in the non-ferrous field as well, and others; describes the numbering system used which is now very widely applied, and then gives very carefully prepared descriptions of electrodes in the E-60 series of classifications. For example, the E-6010 classification is described as giving the best mechanical properties in all welding positions. Some of its characteristics are noted; an indication of its importance as probably the most widely used type; some indication of the maximum welding currents that can be used; physical properties are noted and an idea given of various codes and specifications which would be met generally with this particular E-6010 type.

The A.S.T.M. may publish this Guide as an appendix to the revised Specifications A 233. Numerous changes have been accepted in the specifications, which while making some modification of the present test requirements are primarily intended as clarification by giving more specific definitions of how tests are to be performed.

The new methods of analyzing soaps containing synthetic detergents meet very urgent needs on the part of the Armed Forces and large numbers of soap manufacturers. Huge amounts of soap in this category are being manufactured and, furthermore, in the coming postwar period the use of synthetic compounds will be extended. These new methods have resulted from cooperative work on several samples carried out by a joint committee sponsored by the American Oil Chemists Society and Committee D-12 representing A.S.T.M. This same joint group concerned with soap analysis has developed the revisions in the Standard Methods of Sampling and Chemical Analysis of Soaps and Soap Products (D 460) which provide procedures for analyzing potash soaps, there having previously been no satisfactory method.

The new Specifications for Cast Allyl Plastic Sheets, Rods, Tubes, and Shapes (D 819–45 T) pertain to a group of materials now of commercial importance. They do not cover heat-formed parts and shapes made by assembling two or more pieces. As with most of the other specifications for plastics, detailed requirements are given on light transmission, haze, water absorption, strength, etc., for which tests have been established by Committee D-20.

The recommendations of both of these committees are being detailed in the 1945 annual reports.

Practical Electric Resistance Strain Gage Procedures for Structural Tests on Ships

By W. V. Bassett[1]

SYNOPSIS

Adoption of the electric resistance strain gage for studies of welding stresses in structures has required development of techniques for obtaining consistent results under outdoor and workshop conditions. Gage stability is necessary over longer periods than in other applications. Strain gage procedures are described in this paper which have given results accurate within ±500 psi. in many cases, even under the arduous conditions encountered when making strain measurements on welded ships under construction.

The two fundamental test methods are (1) to observe changes in strains due to operations producing stress in the structure, and (2) to measure relaxation of plugs trepanned or cut out from the structure after the operations are complete. The trepanning method has several advantages in shipboard work.

For the accuracy required in structural tests, the resistance strain gage and associated equipment are entirely satisfactory with respect to calibration and response. The cement bond between gage and metal can follow even plastic strains. Sources of error in structural welding tests are local strain effects, creep in the cement, insulation leakage, poor electrical connections, and temperature effects. These errors are minimized by suitable gage distribution, cementing and waterproofing techniques, rugged wiring and connections, and correct temperature compensation. On outdoor work it is preferable to make strain readings at night when temperatures are more stable.

Wiring problems have been eliminated on several projects by devising a mercury pool connector for making contact directly with the gages. Several other devices and procedures have been developed to improve reliability of strain gage readings and calculations.

In the investigation with which the author is associated, resistance strain gages have been applied to studies of welding stresses on subassemblies, ships under construction and completed ships; as well as structural models. Launching stresses have also been measured.

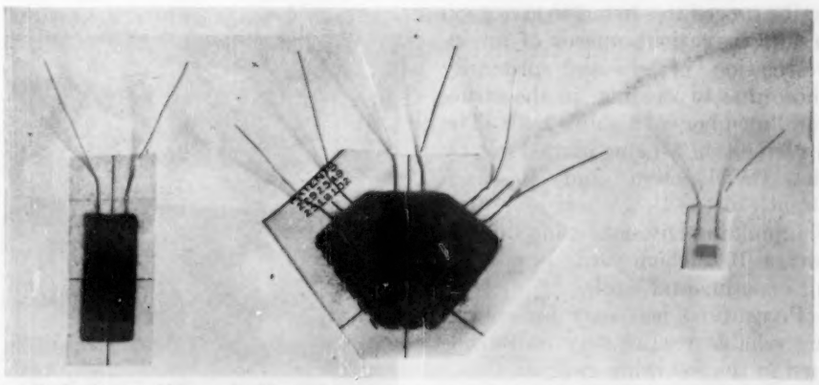
THE versatility and convenience of the electric resistance strain gage recommend it for many applications. In the form now most widely used it is also known as the bonded wire strain gage and depends for its functioning upon the fact that the resistance of a metal wire changes with the strain to which it is subjected. The gage is composed of a length of approximately 0.001-in. diameter alloy wire bonded to thin paper in a pattern to provide a total length subjected to strain equal to several times the gage length. When the gage has been cemented to a structural member, the wire grid is rigidly constrained to undergo the same relative elongation, either tension or compression, as the material to which it is attached. The rather small resistance changes due to strain can be conveniently and accurately measured by as uitable adaptation of the Wheatstone bridge circuit.

Figure 1 shows three gage types. The wire grid is generally covered with felt, as the illustration indicates, for protection and thermal insulation. The wires seen projecting from the felt are heavier leads attached to the grid of fine wire for making electrical connections.

Bonded wire strain gages were first introduced in 1939. Their almost negligible weight and ability to follow extremely rapid strain variations made obvious their applicability to dynamic tests ranging from aircraft flight testing (1)[2] to the shock loads due to impact (2, 3, 4). As further development improved stability of the gages, a much more adequate stress analysis of aircraft fuselages and other structures through static testing was possible (5). In all of these cases the time of loading was too short for appreciable drift of the gage to occur, or drift could be checked by returning to the initial condition.

The convenience of attachment and low unit cost of the wire strain gage made it a logical choice for the several welding stress investigations (6) initiated, in part, by the structural failures of some Liberty ships. Since in this work loading conditions generally cannot be repeated, the gages are required to remain stable over extended periods, usually under the difficult conditions of extremes in weather, interference from building and outfitting work, and tight production schedules encountered in

[2] The bold face numbers in parentheses refer to the list of references appended to this paper.



(a) Single element, $1\frac{3}{16}$ in. gage length. (b) Three element rosette; gages at 0, 45, and 90 deg. (c) Single element, ¼-in. gage length. (For special applications.)

Fig. 1.—Typical Resistance Strain Gages.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia 2, Pa.

[1] Engineer, Development and Research Branch, Central Technical Dept., Bethlehem Steel Co., Shipbuilding Division, Quincy, Mass.

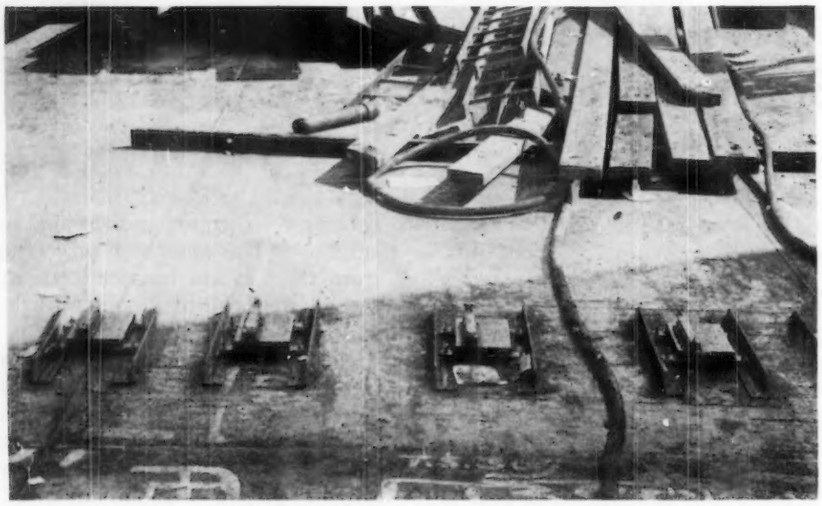


Fig. 2.—Working Conditions on Shipboard.

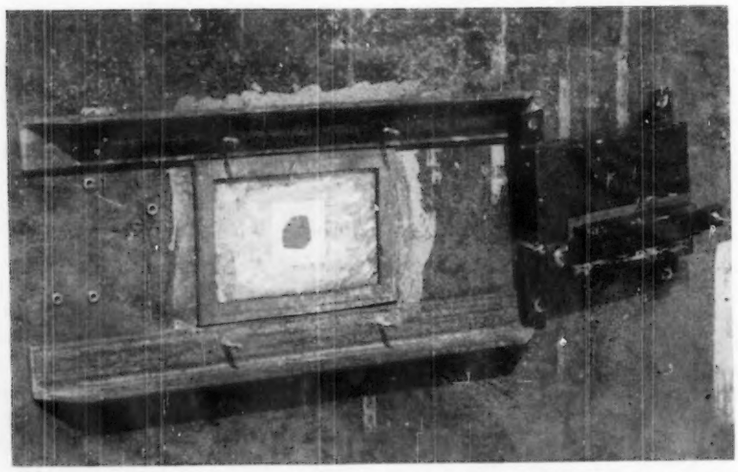


Fig. 3.—Location Adjacent to Butt Prepared for Welding, Showing Strain Gage, Protective Cover, and Watertight Gasket.

the shipyard. The success of such projects depends upon recognition of the factors influencing functioning and stability of the gages and the adoption of suitable techniques. It is the purpose of this paper to describe procedures found to give good results in various phases of an investigation of stresses, primarily those due to welding, in the structural members of a ship's hull. The investigation is being carried out by the Development and Research Branch of the Bethlehem Steel Co., Shipbuilding Division, using ships at several Bethlehem yards as subjects for experimental work.

Precautions necessary for obtaining reliable results may be considered in the following groups:

1. *Location.*—Arrangement of gages to avoid local strain effects, bending due to buckles, for example, which can influence or obscure the effects being measured.

2. *Attachment.*—Adequate bond between gage and metal, requiring cleaning and smoothing of metal surface, choice of a suitable cement, and the allowance of sufficient drying time to prevent creep of the cement.

3. *Functioning.*—(*a*) Elimination of electrical leakage by waterproofing gages and use of high-grade insulation.

(*b*) Dependable electrical connections.

(*c*) Control of temperature effects in the strain gages, electrical equipment, and the structure under investigation.

Test Methods

The two fundamental test methods are (*a*) the normal procedure of reading gages before and after operations which apply load to the structure and (*b*) the trepanning procedure in which strain gages are used to measure relaxation of the plugs of metal to which they are attached as the plugs are trepanned or cut from the structure. The normal procedure gives the change in stress resulting only from the one or more operations occurring in the period between readings, while the trepanning procedure gives the total effect of residual stresses within the structure and stresses applied to the structure. Trepanning is usually carried out by drilling a circle of slightly overlapping holes around the plug, as shown in Figs. 4 and 5. Since the major components of residual or locked-up stress in ships result from a few subassembly and final assembly operations, generally similar results are available by either method.

The normal procedure has the advantages of giving results not directly affected by stresses due to rolling or other previous history of

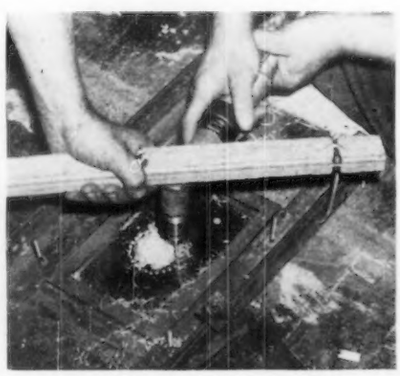


Fig. 4.—Trepanning Gage by Drilling.

Fig. 5.—Making Strain Readings on Trepanned Plug.

the material and of permitting the use of one gage installation for observations during several operations. The investigation can be carried on without any drilling or other permanent defacement of the structure. There are two principal disadvantages of the normal procedure. The first is that gage stability must be relied upon for the periods of several days to several months which may be required to carry out the operations under consideration. The second disadvantage is due to the fact that the cellulose cement type gages generally most suitable for field work have been found subject to an initial shift in strain indication when exposed to a temperature over 140 F. While the gages are not actually damaged until a somewhat higher temperature is reached, inconsistent readings may result. Consequently gages located less than about 9 in. from welding have not been considered dependable. According to one investigator, gages are more stable at relatively high temperatures if carried through an initial cycle to a temperature higher than that to be encountered in service before starting to take readings.

The trepanning procedure is performed after welding and other operations have been completed and requires one or two days, or, if special procedures are followed, only a few hours. The gages are exposed to accidental damage only during the time required for cementing gages and drilling out the plugs, and are required to remain stable only between the readings before drilling and after drilling. For these reasons the trepanning method is usually more satisfactory for shipboard work despite the disadvantages that holes left by the plugs must be repaired and the necessary crew and equipment are more extensive than required for the normal procedure. Stresses in and adjacent to welds can be determined by the trepanning procedure. In such regions of steep stress gradients the result must be recognized as an average value over the area of the trepanned plug.

Strain Gage Designs

Bonded wire strain gages are available as single-element gages with gage lengths ranging from $\frac{1}{8}$ in. to 6 in. for use when the strain component in a given direction is desired, and in a variety of "rosette" patterns for determining direction and magnitude of principal strains where the orientation of strain distribution is unknown. When working with ships the fore-and-aft and transverse strain components are frequently of as much interest as the principal strains. In the case of welds, strains longitudinal with and transverse to the welds are required. In both cases the "fan" pattern rosette (gages at 0, 45, and 90 deg.) can be aligned to give right-angle components directly. The "delta" rosette is less convenient for these purposes in that right-angle components are not directly apparent from inspection of the gage readings.

The rosette types just mentioned give the three strain measurements required to define analytically the principal stresses at a point (**7**). Four-element rosettes provide an additional reading which can be used to check accuracy of the other readings. The check is particularly simple with the type of rosette composed of two gage elements at right angles, the remaining two elements, also perpendicular to one another, being located 45 deg. from the first pair. The algebraic sum of strain indications by one pair of gages at right angles should equal that of the other pair.

The gage wire grid has a projected width which, while small compared with the total length, will nevertheless vary resistance slightly in proportion with strain components transverse to the gage axis. Baumberger and Hines (**8**) state that the maximum error due to neglecting the "lateral strain effect" is about ±3 per cent, and provides a complete development of formulas for taking the effect into account.

Strain Gage Installation

Location:

In a plate or member assumed to have uniform stress over a cross-section, the actual strain is likely to be far from uniform. Local bending strains due to buckled plate or loads not quite centrally applied and unsymmetrical welding shrinkage effects can alter or obscure the direct strain measurement generally desired. The indication of a gage on only one surface of a plate has been found, for these reasons, to be 10 per cent in error as a measure of direct strain in the case of a plate which was apparently straight, and 35 per cent in error where a certain degree of buckling was apparent.

For plates, the practice of locating gages on both sides and using the average strain indication from each pair of opposite gages as a measure of direct strain minimizes error due to bending. Severely buckled plates should be avoided in any case as they cannot be expected to develop the same direct stress as straight plate for a given applied strain. Measurement of direct load carried by a structural shape requires selection of several gage locations at the cross-section in question to determine stress distribution and the average direct stress.

Cementing:

In securing an adequate bond between gage and metal, the first step is complete removal of paint, rust, and scale, leaving a smooth bright metal surface free from noticeable scratches, Fig. 6. A flexible-disk power grinder is very satisfactory for this purpose. The next step is to clean the area to remove every vestige of oil and grease, preferably just before cementing gages. The surface is swabbed with absorbent cotton soaked with acetone, then immediately rubbed dry with clean cotton. This process is repeated until the dry cotton shows no trace of discoloration.

A number of cements are suitable, most of them composed of celluloid dissolved in a volatile solvent. While all may be equally satisfactory when thoroughly dry, the drying time varies considerably. For the older style gage made on relatively heavy paper, several com-

Fig. 6.—Gage Locations Ground and Smoothed, Including Location on Weld.

mercially available cements are widely used. A 24-hr. drying period is recommended by one gage manufacturer, during the first half hour of which mechanical pressure is necessary. New style "quick-drying" gages are now available. When used with cement prepared by the manufacturer, they require only finger pressure for about half a minute when attached, and the recommended drying time is 6 to 8 hr. On account of the convenience of attachment, the "quick-drying" gages are being considered for general use even where the rapid drying feature is not important.

If reasonable care is used in attaching gages, there is usually no question of the reliability and constancy of the "gage factor" relating gage indication with actual strain, even for strains well into the plastic range. The real goal of cementing technique is to obtain a bond sufficiently free from creep over the time interval involved in the test, with a reasonable drying time under the prevailing atmospheric conditions. The recommended drying times mentioned in the preceding paragraph presumably refer to ordinary surroundings at room temperature and should be extended in case of cold or dampness, or artificial heating should be used. In outdoor work on shipboard the practice of preheating the location before gage installation and applying heat again for a period before waterproofing the gage has been adopted for all but ideal warm-weather conditions. Heating elements built into protective covers and portable 200-w. lamps with reflector bowls are proving very convenient for this purpose. While many tests of cementing methods have undoubtedly been made under various drying conditions, most of the results have not been compiled and made generally available.

Waterproofing:

The need for waterproofing gages is readily apparent when it is realized that a leakage path of 1 megohm resistance between the terminals of the usual strain gage of 120 ohms resistance will have the same effect on strain indication as a stress of about 1800 psi. The paper on which the gage is made can absorb enough moisture from a reasonably humid atmosphere to provide an appreciable parallel path. In practice gages are coated with melted wax, preferably petrosene or ceresin, applied with a brush as soon as the proper cement drying time has elapsed.

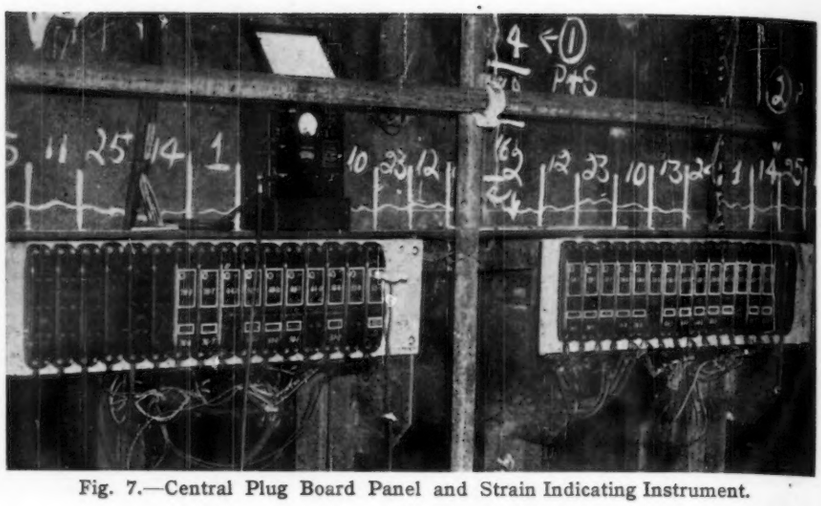


Fig. 7.—Central Plug Board Panel and Strain Indicating Instrument.

While a change in parallel leakage resistance between gage terminals cannot be distinguished from a change in strain, the resistance between the gage grid and the plate to which it is attached, and between the elements of a rosette, provides a satisfactory measure of the magnitude of possible errors. A portable battery-operated megohmmeter which applies a maximum test voltage of 25 v., sufficiently low to avoid damage to the gage, has been of definite aid in judging whether moisture can have affected a series of readings. It has also been found desirable to check wiring connecting strain gages to instruments.

Gages located on shipboard require protection from physical injury and the weather in addition to waterproofing. Figures 3 and 11 show two types of protective enclosure which have proved successful.

Strain Indicating Equipment

The self-contained portable strain indicator, Fig. 7, developed especially for use with the resistance gage, has a slidewire Wheatstone bridge circuit supplied with 1000 cycle alternating current from a battery-operated oscillator. The bridge unbalance is amplified in a vacuum tube amplifier and indicated on a milliammeter. Use of alternating current has the advantage of cancelling out thermo-electric effects in the gage circuit. The fundamental characteristic of any bridge circuit is its sensitivity in detecting the change in an electrical resistance relative to the approximately equal resistance, in this case, against which it is balanced. The fact that relative change between the two resistances determines bridge balance is used to provide compensation for the effect of temperature on the gage and the metal to which it is attached.

Effects of Temperature Change:

The indicated resistance of an installed strain gage varies with temperature as well as with strain and absorbed moisture, as previously noted. The variation with temperature is a combination of the coefficient of resistance for the gage wire, generally relatively low for gages to be used in static tests, and the coefficients of expansion of the wire and the material being tested. The circuit can be made self-compensating for temperature by using as the "dummy" resistance, against which the strain gage resistance is balanced, another gage from the same manufacturer's lot as the strain gage. The dummy or compensating gage is attached to an unstressed piece of the material used in the structure under test. A temperature change unaccompanied by change in the stress pattern will affect the strain and compensating gages equally, with no resultant effect on instrument indication.

Correct temperature compensa-

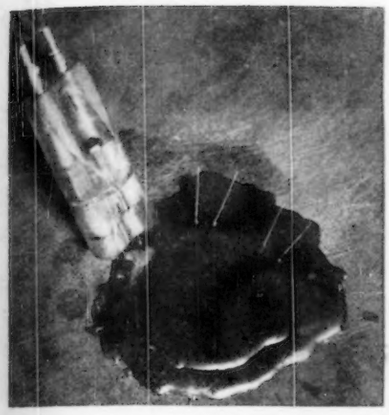


Fig. 8.—Waterproofed Gage and Mercury Connector.

tion requires that strain and compensating gages be at the same temperature, or at least that constant temperature differential be maintained. For this reason, several dummy plates carrying the compensating gages are distributed over the strain gage layout. Each dummy plate is located so as to follow the same temperature variations as the group of gages which will be connected with it for readings. The closest possible thermal contact between dummy plates and the metal of the structure is required. Appreciable differences between temperature of the structure and that of the atmosphere, or sudden temperature changes, make it necessary to provide insulation and shelter over the dummy plates. Since sunlight and shadows result in rapid temperature fluctuation during the day, with consequent rapid changes in stress pattern as well as compensation difficulties, it has become the practice in work on outdoor structures to make all strain gage readings at night after temperatures have stabilized.

A lesser temperature effect is due to the coefficient of resistance of the wiring. For accurate work where appreciable temperature change could be expected, strain gage and dummy leads have been made equal in length and of the same kind of wire. The use of fairly heavy copper wire, no smaller than No. 18, reduces the total resistance and, therefore, errors from this source.

The remaining effect of temperature change, that on the "zero" of the strain indicator, can be appreciable when the instrument is brought from a warm room to outdoor conditions. The zero has been taken as the instrument balance point which would result if dummy and strain gage resistances were exactly equal. Since the two resistances in general are not exactly equal, the balance point will be above or below the zero point. If now the gages are interchanged between the strain gage and dummy gage positions, the difference from the zero will be in the opposite direction. The average of these two instrument readings will be the zero point.

Electrical Wiring and Connection Resistance:

In using the resistance strain gage for structural stress analysis, one of the important problems is that of connecting a large number of gages, one after another, into the bridge circuit for taking readings. In cases where each gage is to be read more than ten or fifteen times, all gages may be wired to one or more central instrument locations. Simple wiring arrangements using well-insulated heavy copper wire, preferably solid conductor, with a minimum of changeable connections are desirable. Schemes using a common return have not been used in field work because, despite considerable care in gage installation and protection, one or two grounds are frequently found in each gage layout. Locating the grounds would require cutting the wiring assembly into small sections for checking, then reassembling.

The connection problem is complicated by the fact that variations in the resistance of changeable contacts between readings directly affect accuracy of the data. For example, a change in contact resistance of 0.016 ohm in the circuit of an ordinary 120-ohm gage has an effect on strain indication corresponding to a 2000-psi. stress change. Connections made with copper or brass binding posts and clean lugs have proved entirely satisfactory. Readings can be reproduced well within the accuracy of setting the strain indicator. Heavy brass plugs and jacks, Fig. 7, can be changed more rapidly and are equally satisfactory. Switches are generally undesirable for use in the bridge circuit. Even high-grade switches, while apparently reliable at first, give erratic results on account of wear and dirt after a period of use.

Portable Mercury Pool Connector:

A convenient solution to the problem, especially where relatively few readings of each gage are required, is to use a portable connector with a single pair of leads to make contact directly with the small connection wires on the gages themselves. The work involved in installing wiring and identifying terminals is thereby avoided. In trepanning work any attached wires are likely to be damaged in the drilling operation. The two obstacles to the use of a portable snap clip connector are contact resistance and the possibility of damage to the comparatively fine wires extending from the strain gages if subjected to several clamping operations.

The development of a mercury connector, shown in Figs. 5 and 8, consisting of a small plastic receptacle which contains two mercury pools has overcome these difficulties. When taking a reading, the ends of the gage wires, carefully cleaned of any wax or cement, are inserted through holes in rubber diaphragms into the mercury. An entirely satisfactory contact between the gage and the lead wires results. The diaphragms, even after several hundred readings, retain the mercury when the connector is held in any position or even shaken, yet no difficulty is encountered in making contact with one gage after another as rapidly as the indicator operator can observe and record the readings. Diaphragms are replaced when worn. The mercury connector has been used with success on several fabrication tests and in trepanning measurements on a number of ships. The only limitation to its use that has been found is weakening of the gage connection wires on account of amalgamation with the mercury. The wires can be expected to last for at least fifteen readings, which will cover all trepanning tests and most fabrication tests.

Notes on Procedure

Standardization:

When inconsistencies are found among a series of readings, the possibilities of erratic behavior of one of the dummy gages, instrument zero

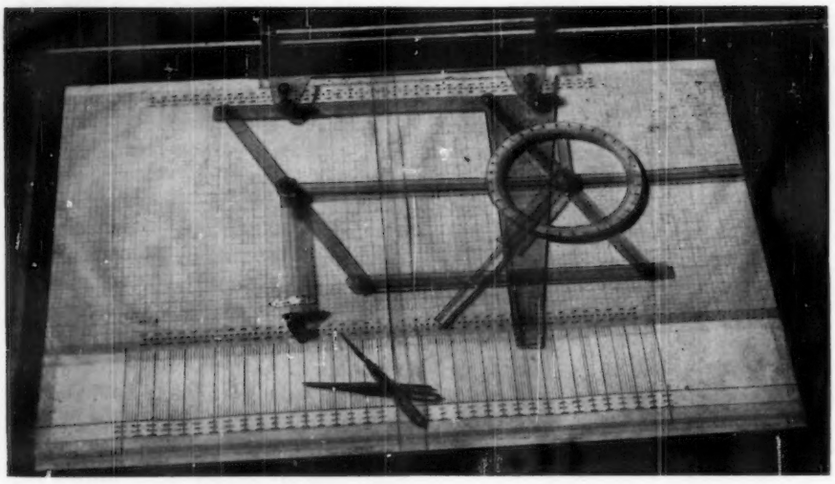


Fig. 9.—Geometrical Computer for Determining Principal Stresses from Rosette Readings.

variation, and change in resistance within the portable leads and connector are likely to be brought up. It has been found desirable to keep track of these three items by following a regular "standardization" procedure during the course of a set of readings, though the effects are seldom of sufficient magnitude to justify their being taken into account as corrections. Dummy gages are periodically compared with an adjacent dummy or with a standard. Instrument zero and mercury connector standardization is facilitated by a zero check dummy. This device contains two gages selected, for convenience, to have nearly equal resistance. Four terminals are arranged to permit connecting the gages in both direct and interchanged positions. In addition, set screw terminals to accommodate a pair of discarded gage connection wires are provided leading to one of the gages, for use in testing the mercury connectors. The difference in indication between reading the gage through the connector leads and through the terminals is a measure of connector resistance.

Calculation:

The strain indicator gives readings of relative elongation in millionths of an inch (microinches) per inch which, for purposes of analysis, are generally converted to stress. Stress components from a pair of mutually perpendicular gages are easily computed using the modulus of elasticity and Poisson's ratio. The calculation of principal stresses from rosette readings is based on Mohr's circle. An article by Murray (**9**), followed by several informative discussions, fully describes Mohr's circle as adapted to rosette analysis. The solution can be carried out by several methods, among them the following: (1) graphical, (2) mathematical analysis using calculating machine, (3) geometrical computer, and (4) nomograph or alignment chart. The graphical method requires no particular setup and is satisfactory when doing a few calculations, but becomes tedious when many calculations are required. The considerable effort spent in resolving the algebraic and trigonometric expressions derived from Mohr's circle into a simple tabular form for calculating machine solution has proved worth while, for the machine method has become standard in this investigation. The geometrical computer, Fig. 9, is sufficiently accurate for checking and, since it is much faster and subject to mistakes of an entirely different nature, provides an excellent check method. The nomograph has been investigated and has been found to offer the same advantages as the geometrical computer.

Applications and Reliability of Results

General:

Accuracy which may be expected from measurements with resistance strain gages depends upon the nature of the application. A change in stress as small as 100 psi. can be detected, and in a short-time reproducible test the combined effect on strain indication of all errors has been found to be less than $\pm 1\frac{1}{2}$ per cent. Possible limitations to accuracy for the test of short duration, as long as $\frac{1}{2}$ hr. under ordinary indoor conditions, are adequacy of the cement bond, consistence of gage response and calibration accuracy, reproducibility of connection resistance, instrument precision, and instrument reading error. In these respects the resistance strain gage technique may be considered beyond reproach for providing the degree of accuracy required in most structural strain measurements. Errors limiting the accuracy of structural tests, primarily gage creep and the influence of temperature change, are functions of time rather than of the strain being measured and are consequently more properly expressed as a margin than as a percentage.

Gage creep is apparent as a drift in the strain indication when there has been no corresponding change in loading. The direction of drift is frequently opposite to that of the strain which has been applied to the gage, which would indicate that the gage is seeking to return to its original condition. However, in other cases the gage drifts in the direction of the applied strain. Whether this represents creep of the metal or drift from a source within the gage itself has not been determined in this investigation.

Temperature variation while gages are being read or a different temperature distribution at any reading from that at the initial reading results in more or less inconsistent data. While procedures can be adopted to tie in temperature observations with strain gage readings to correct for the irregular drift in indication due to compensation errors, alteration of the actual stress pattern cannot be easily taken into account. It may be noted that such tests on the compensation effect as have been made as part of the work described show the single element gages to be practically perfect in this respect, while small discrepancies may be found between elements of a rosette when used over a wide temperature range.

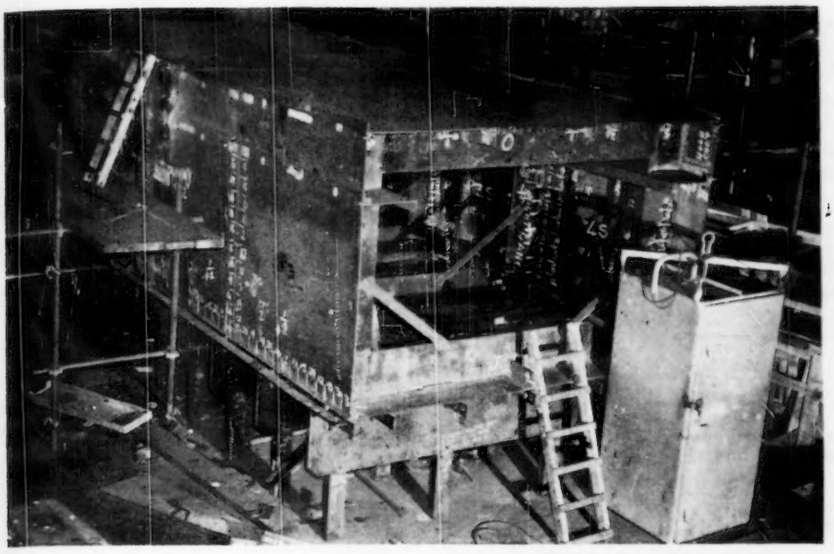


Fig. 10.—Structural Model for Study of Girth Weld Sequence.

Residual Stress Pattern in Deck and Shell of Ships:

The first extensive application of electric resistance strain gages in the present investigation was for determination of the residual stress pattern in portions of the deck and shell of Liberty and Victory ships, using the trepanning procedure. Rosette gages were attached on both sides of the plate at each location. Initial readings were taken in the evening when temperature conditions had stabilized, after which the plugs were drilled out. Final readings were taken on the ship, sometimes with the plug still held in place by one ligament, as soon as the plug had returned to ambient temperature following trepanning.

An additional source of error present in this work was the possible detrimental effect of the trepanning operation on relaxation of the plug and performance of the gages. Studies made by other investigators have indicated that the trepanning procedure is sufficiently reliable for use in structural stress analysis. No direct check of accuracy was possible in the work described here, since any comparison involved inevitable differences between locations on the same or different ships. A composite plot of stress adjacent to a seam weld in deck plating, Fig. 12, based on measurements by trepanning at three different locations on one ship, shows a maximum spread of about 3000 psi.; most of the points being in better agreement.

The residual stress pattern in a completed ship is the summation of initial residual stresses in the plate such as those due to rolling, forming and flame cutting, welding stresses set up in subassembly operations, final assembly welding stresses, and the stress patterns due to hull loading condition and temperature distribution. Separate studies of all these components are being made.

Girth Welded Investigation with Structural Model:

The effect of the sequence followed in making a girth weld on residual stress distribution is being studied with a model, Fig. 10, representing the amidships portion of a Liberty or Victory ship to approximately one-fifth scale. Gage locations are distributed both forward and aft of the weld. When strain readings following one girth weld sequence have been completed, the model is cut apart, stress relieved, and reassembled by another girth weld sequence. Since strain gages of the ordinary type used on the model would be ruined by the stress-relieving temperature, new gages are used for each sequence.

Figure 13 shows part of a stress pattern obtained from the model. It is believed that the results are accurate within a range of about 1000 psi., sufficient to give a picture of the pattern of stress as well as the approximate magnitude. Since initial and final readings were taken within three to five days of one another, gage creep was not serious. Although the model was located indoors with a view to avoiding temperature problems, the normal daily variation within the shop and drafts from frequently opened doorways gave some trouble.

Results obtained with the model have been decidedly encouraging. Radically different residual stress patterns, generally consistent with welding theory, have been obtained from each of the three welding sequences so far investigated, though the maximum stress values were approximately the same. A girth weld sequence on a full-size ship has been analyzed with strain gages with the intention of repeating the sequence on the model to provide information on the scale effect.

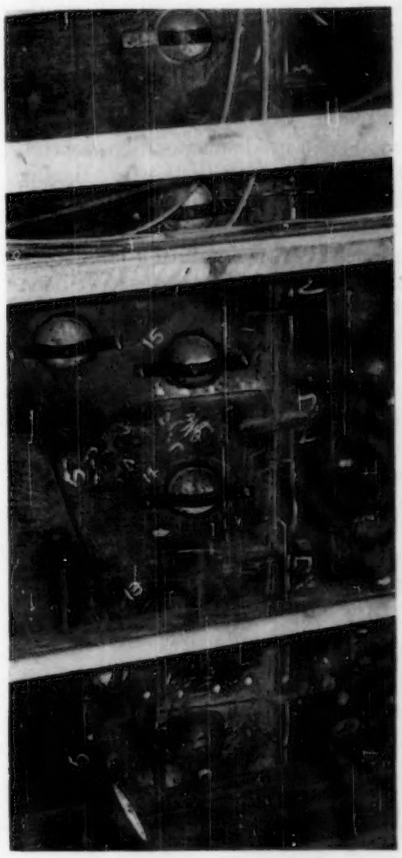


Fig. 11.—Shipboard Strain Gage Installation, Showing New Type Protective Cover.

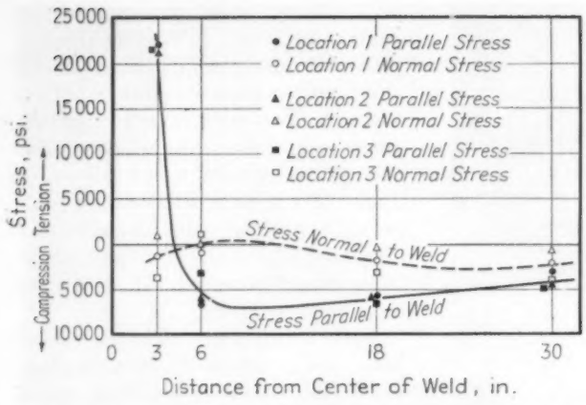


Fig. 12.—Typical Stress Pattern Adjacent to Weld in Deck Plating of a Ship, Obtained by the Trepanning Method.

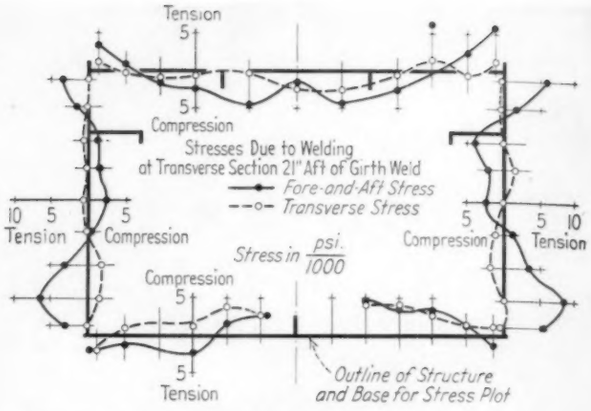


Fig. 13.—Typical Stress Pattern Obtained from Structural Model.

Long-Time Tests:

For strain measurements extending over a period of months the bakelite type strain gage is probably better suited than the ordinary cellulose cement type gage, although some results have been obtained with the latter type during construction of a cruiser hull. Such tests should be run in conjunction with creep tests of gages attached under exactly the same atmospheric conditions.

Launching Stresses:

The "static" strain indicators have been used successfully to catch the peak stresses in the hull during launchings of several vessels ranging in size from landing barges to heavy cruisers. The magnitude and location of the highest stresses have been determined. These studies have been of interest for comparison with calculated stresses during launching, which provides an opportunity for a full-scale test of the hull structure under loads approaching working conditions. The program will be extended to include a continuous strain record throughout launching obtained by means of a multi-element oscillograph. Results obtained by the rather makeshift strain indicator method are believed correct to within about 10 per cent.

Weighing Rod:

A weighing rod 3 in. long was constructed of $1\frac{1}{8}$ in. diameter steel rod for use in studying the deflection of a reciprocating engine crankshaft without removing it from the bearings. Load was applied by jacking. Strain gages were attached 90 deg. apart around the circumference of the rod. This application emphasized the necessity for considering non-axial loading in locating gages, for despite every effort to line up the jack and weighing rod, when jack pressure was applied one or another of the gages at first showed tension. As the contact surfaces of the rod deformed to centralize the load, distribution of compressive stress became more uniform; although in no case could one of the gages alone be relied upon. The average of the four gage readings was used as a measure of load.

Conclusion

The electric resistance strain gage has been found a valuable tool for stress analysis on structures. Test methods and techniques are in use or can be devised to provide stress measurements of accuracy sufficient for practical purposes in almost all problems which may be encountered. Conditions imposed by work out of doors, on shipboard, or in the shop have required that the characteristics of the equipment be recognized and suitable precautions taken to eliminate or minimize the inherent errors.

Acknowledgment:

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References

(1) C. R. Strang, "Progress in Structural Design Through Strain Gage Technique," *Journal*, Soc. Automotive Engineers (*Transactions*), Vol. 50, No. 8, p. 346 (1942).

(2) R. O. Fehr and E. R. Parker, "Measurement of Dynamic Stress and Strain in Tensile Test Specimens," *Experimental Stress Analysis*, Vol. I, No. 1, p. 76 (1943).

(3) A. V. deForest, "New Pathways in Engineering," *Metal Progress*, Vol. 43, No. 5, May, 1943, p. 719.

(4) C. O. Dohrenwend and W. R. Mehaffey, "Measurement of Dynamic Strain," *Journal of Applied Mechanics*, Vol. 10, No. 2, p. A-85 (1943).

(5) A. H. Flax and M. C. Wardle, "Application of Electric Strain Gages to Aircraft Design Problems," *Experimental Stress Analysis*, Vol. II, No. 1, p. 51 (1944).

(6) F. G. Tatnall and C. H. Gibbons, "Static and Dynamic Testing of Structures," The Society of Naval Architects and Marine Engineers. 1944 Annual Meeting.

(7) M. M. Frocht, "Photoelasticity," John Wiley & Sons, Inc., New York N. Y. (1941).

(8) R. Baumberger and F. Hines, "Practical Reduction Formulas for Use on Bonded Wire Strain Gages in Two-Dimensional Stress Fields," *Experimental Stress Analysis*, Vol. II, No. 1, p. 113 (1944).

(9) W. Murray, "An Adjunct to the Strain Rosette" and discussions by J. H. Meier, H. M. Hansen, and R. Baumberger, *Experimental Stress Analysis*, Vol. I, No. 1, p. 128 (1943).

General Properties of Industrial Radiographic Films

By Herman E. Seemann[1]

EDITOR'S NOTE: This paper is intended for ultimate publication as a chapter in a comprehensive manual on radiography. The individual chapters will receive preliminary publication in the BULLETIN in order to elicit discussion, of which cognizance will be taken in preparing the final publication.

X-RAY films consist of a radiation-sensitive emulsion usually coated upon both sides of a transparent sheet material called the "base." As the name implies, the function of the base is to furnish the support for a substance which is necessarily so thin and delicate that it could not otherwise be handled conveniently. The thickness of the base is sufficient to provide the required stiffness for safe handling of the sensitive emulsion and still not be so thick as to introduce objectionable parallax. A blue tint is commonly incorporated to give the radiograph a pleasing appearance, particularly when viewed with incandescent lamps. As a rule the principal constituent of the base is cellulose acetate. "Hazards of this slow-burning film when in use are judged to be small, and, in storage, somewhat less than would be presented by common newsprint paper in the same form and quantity."[2]

All photographic emulsions have some degree of sensitivity to ordinary light and to X-rays and gamma rays. X-ray films are made especially sensitive to X-rays and gamma rays, and the screen-type films are also particularly sensitive to blue light, the color emitted by most intensifying screens. Most of the direct-exposure class of films are slow to light. This is only natural since, being designed for X-rays or gamma rays, little consideration is given to their light-responsive characteristics. It should be remembered that stray radiation—light, X-rays, or gamma rays—in sufficient quantity, will fog any photographic or radiographic film or paper.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia 2, Pa.

[1] Physicist Physics Dept., Eastman Kodak Research Labs., Eastman Kodak Co., Kodak Park, Rochester, N. Y.

[2] Quoted from Underwood Laboratories, Inc. MH1273.

X-ray film emulsions, like most other photographic film emulsions, consist of a suspension of minute crystals, principally silver bromide, in gelatin (Figs. 1 and 2). These crystals or "grains" require considerable magnification to be seen. When affected by radiation, a minute part of the crystal separates into the silver and bromine of which it is composed. Upon *development*, the rest of the silver is freed and the entire grain is finally transformed. Thus, the developing process is essentially one which completes the process started by the radiation. Silver in this finely dispersed state appears black, the different degrees of blackening representing different numbers of developed grains per unit area (see Fig. 3). Only a few of the unexposed silver bromide grains are affected by the developing solution in the normal times of development. (See "Fog.")

Before development, the silver bromide which has been exposed contains the *latent image*. The ordinary latent image cannot be seen; in fact, no physical test has yet been devised which will detect the presence of such a minute amount of free silver. If a film is *greatly* overexposed, the image will show to some degree without development, but it is then worthless when developed.

It is necessary to remove the undeveloped silver bromide from the film because it would eventually turn dark on continued exposure to

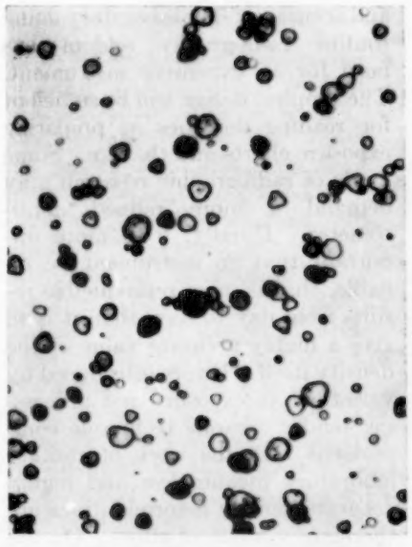

Fig. 1.—The Silver Bromide Grains or Crystals of an X-ray Emulsion (×2500).

In the actual coating, they are much more closely packed, but they have been dispersed here to show their size range and shape more clearly.

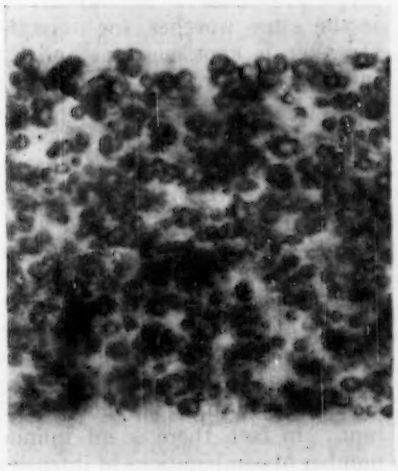

Fig. 2.—Cross-Section of the Emulsion Coating on One Side of an X-ray Film (×2500).

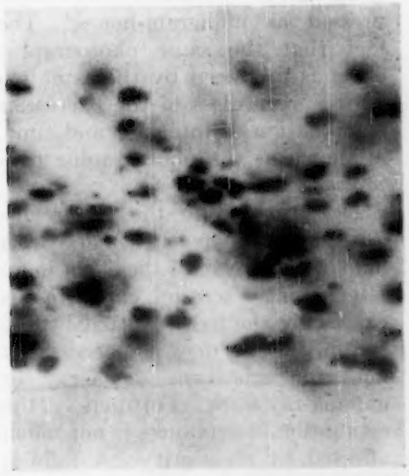

Fig. 3.—Cross-Section of Exposed and Processed X-ray Emulsion of Moderate Density (×2500).

Note the small number of developed grains compared to the total in Fig. 2.

light and thus ruin the radiograph. The *fixing bath* dissolves the silver bromide, leaving the silver image which was brought out by the developing solution. The active ingredient for dissolving the silver bromide may be sodium thiosulfate or ammonium thiosulfate, but other substances are included in the bath to harden the gelatin and to neutralize the developer carried over in the film.

Film Characteristics

It is a familiar fact that the blackening in the radiograph depends both upon the *intensity* of the radiation and upon the *time* of the exposure. For X-ray and gamma-ray work (with or without lead screens),the effect in the radiograph, is the same whether, for example, the time is kept constant and the intensity is doubled *or* the intensity is kept constant and the time doubled. Expressed mathematically, the exposure $E = It$, that is, the exposure is the intensity multiplied by the time. It is apparent, then, that the effect of a given exposure on the film will be the same so long as the product of the intensity and the time is the same. An exposure of 20 ma.-min. may be obtained with 1 ma. and 20 min., or 2 ma. and 10 min., or 4 ma. and 5 min.; in fact, there is an infinite number of combinations of intensity and time which will give 20 ma-min. and therefore have the same effect on the film. For gamma rays from radium, exposure may be expressed as milligram-hours. The fact that the same photographic effect is produced by the same exposure, regardless of the particular combination of intensity and time, is known as the photographic *reciprocity law*.

Deviations from the reciprocity law occur in exposures made with light. Since most of the effect in an intensifying screen exposure is caused by the light emitted by the screen, the law does not necessarily hold for this type of X-ray or gamma-ray work. Fortunately, the estimation of exposures is not much affected by reciprocity law failure, because milliamperes and minutes are not usually varied over great extremes. In the examples cited in the preceding paragraph, it is not likely that deviations from the reciprocity law would be serious. The selection of 0.1 ma. and 200 min. (!) to obtain 20 ma-min. might give a very different result.

The degree of blackening in a radiograph is properly called *photographic density*, or simply *density*, if there is no risk of confusion with other meanings of this word. Photographic density is defined by the equation $D = \log I_0/I$, where I_0 is the intensity of the light falling on the area being measured and I is the intensity of the light transmitted by this area. (In this chapter, "log" refers to the common logarithm of a number, that is, a base of 10.) The following table illustrates the relation between density and the percentage of light transmitted.

$\frac{I_0}{I}$	Density $\log \left(\frac{I_0}{I}\right)$	Transmission, per cent
1.0	0.0	100
2.0	0.3	50
4.0	0.6	25
10.0	1.0	10
100	2.0	1.0
1 000	3.0	0.1
10 000	4.0	0.01
100 000	5.0	0.001

From this table it is apparent that an increase in density of 0.3 decreases the transmitted light to one half its former value.

A *densitometer* is a photometer especially designed for measuring film densities. Both visual and photoelectric types are in use. As with most instruments, there is a fairly consistent relation between price and accuracy. The laboratory doing routine radiography seldom has need for an expensive instrument. The simplest design will be sufficient for reading densities in preparing exposure charts and the like. Some kinds of radiographic research may demand a more refined densitometer. Usually, it is more important that an instrument be reliable, that is, give reproducible results from day to day, than it is to give a highly accurate value of the density itself. Errors introduced by variations in exposure and processing render *accurate* technique comparisons with the work of another laboratory meaningless and highly accurate density determinations are therefore a waste of effort. On the other hand, the use of a reliable densitometer within any one laboratory facilitates the study of variables which arise locally in exposing or

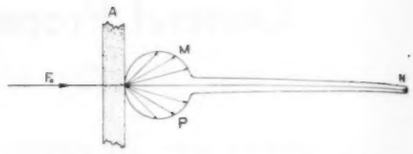

Fig. 4.—Part of the Ray of Light, F_0, Is Absorbed in the Photographic Deposit, *A*, but of That Which Is Transmitted Some Is Scattered, and Some Continues in the Original Direction.

processing. Dependability is more important than accuracy since *changes* in density are likely to be of more interest than the densities themselves.

Figure 4 shows how a beam of light, F_0, is transmitted by a developed film, A. Some of the light is, of course, completely absorbed by the silver particles, but of that which passes through, some is scattered, as at M and P, while some, N, continues in the direction of the original beam. It is obvious that the amount of light collected by a densitometer will depend upon the manner in which the diaphragming system is arranged around MNP. A large opening near A will permit all the light to enter the measuring instrument while a small opening some distance away will admit only the component N. In the former case, the density measured is called "diffuse density," and in the latter case, "specular density." Diffuse density is less than specular density since more light is collected. The results of reading a given density on different instruments will thus depend upon their design. It is the reproducibility of densitometer readings rather than the particular kind of density which is important.

Under average conditions of viewing radiographs on an illuminator diffuse density is generally applicable. A given point on the radiograph receives light from the flashed opal glass, which is a fairly diffuse source, and a narrow beam is received by the eye.

The different densities in a radiograph are caused by the different X-ray (or gamma-ray) intensities transmitted by the various parts of the specimen. Since the *time* of exposure is the same in all areas of any one radiograph, the exposures in the different areas are proportional to the X-ray intensity. Thus, in the

equation which defines exposure ($E = It$), E, the exposure at any point, is equal to a *constant* times the intensity at that point. This equation gives no information about the relation between *density* and exposure. The quantitative relation between the exposure and the resulting density is given by the "characteristic curve" (sensitometric or H and D curve). This is obtained by plotting density against the common logarithm of the *relative* exposure. Since standard units suitable for expressing radiographic exposures have not been devised, the only alternative is to express the exposures of a series in terms of one of them, that is, the values will be relative. The disadvantage of not being able to express radiographic exposures in standard units is not so great as might at first be supposed.

A series of known gamma-ray exposures may be made by setting up films at a fixed distance from the source of radiation and removing them, one by one, at different times. If the reciprocity law is accurately obeyed, curves obtained by this method will have the same shape as if they had been exposed to different intensities. Thus, a curve obtained by the time-scale method can be used for evaluating relative intensities. (If several films were set up at different distances and exposed for the same time the different intensities would be computed from the inverse square law.) It is usually much more convenient to make X-ray sensitometric exposures on a time scale because of the lack of space in the uniform part of an X-ray beam for distributing films at different distances without overlapping films or their supports. Furthermore, a correction for air absorption may be necessary. As with gamma rays, time-scale results are similar to those obtained on an intensity scale, assuming the validity of the reciprocity law.

Attention must be paid to the possibility of errors arising from scattered radiation, particularly when using different distances to obtain an intensity scale. Under such conditions, some films may be near a scattering body, such as the wall, while others are far away. During time-scale exposures to gamma rays, conditions of temperature and humidity should remain reasonably constant to make sure that all films are treated alike. Gamma-ray exposures are usually long enough so that, in using the time-scale method, films exposed in the early part of the period may not be subjected to the same atmospheric conditions as those exposed for the entire time unless some precautions are taken.

Figure 5 shows a lead sector wheel used in controlling exposures in X-ray sensitometric studies. It is rotated once (or more if necessary) in front of the film at a constant speed. Since the angle of arc subtended by each opening is accurately known, the relative exposure time is also accurately known. The lead should be laminated between steel or

Fig. 5.—Lead Sector Wheel Used in X-ray Sensitometry.

brass plates to give the necessary rigidity. In estimating the thickness of lead required, it should be kept in mind that the exposure *through the lead* during one revolution must be small compared to that made through the smallest sector *opening*. Since constancy of X-ray output during the exposure is essential, it may be well to provide an auxiliary lead shutter which is kept closed until steady conditions are established. This shutter is opened for a sensitometric exposure only when the film is completely covered by the lead of the sector wheel. Another method for obtaining such a series of exposures is to move the film holder out into the X-ray beam from behind a heavy lead protective plate. (See Fig. 6.) To avoid backscatter, the X-ray beam which passes through the film and holder should not strike any other material until a considerable distance away. The advantages of this system over that of the sector wheel are that the lead protection may be made very heavy without overloading the driving mechanism and any kind of time series desired may be chosen. However, unless the system is automatically driven, timing errors may occur. The sector wheel is free from timing errors if accurately made and rotated at a uniform rate. There is no need for the operator to go into the X-ray room when the X-ray tube is turned on since remote control can be effected with electromagnetic devices. In fact, electrical remote control can be made very simple and more reliable than direct hand control.

The mechanical design of the rotating sector wheel type of sensitometer for kilovoltages up to about 100 is reasonably simple, but for higher kilovoltages the moving film type seems preferable since much more lead is needed for shielding the film against both primary and secondary rays. Sensitometry with gamma rays and very high voltage X-rays requires great care because it is almost impossible to reduce the intensity of unwanted primary radiation to a negligible value by absorption in lead and the scattered rays are also exceedingly penetrating.

Interpretation of the Characteristic Curve

The various densities obtained in exposures described in preceding paragraphs are plotted against the logarithms of the relative exposures. The shape of the curve obtained will depend upon the type of film, its time of development, and other factors. Information which may be obtained from *characteristic curves* will be discussed by referring to Fig. 7, this particular curve being chosen

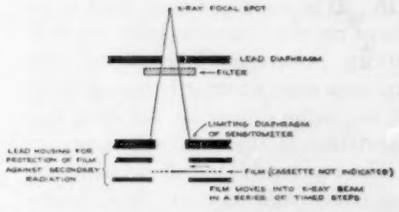

Fig. 6.—Sensitometer Used with Hard X-rays.

All parts are stationary except the film and cassette.

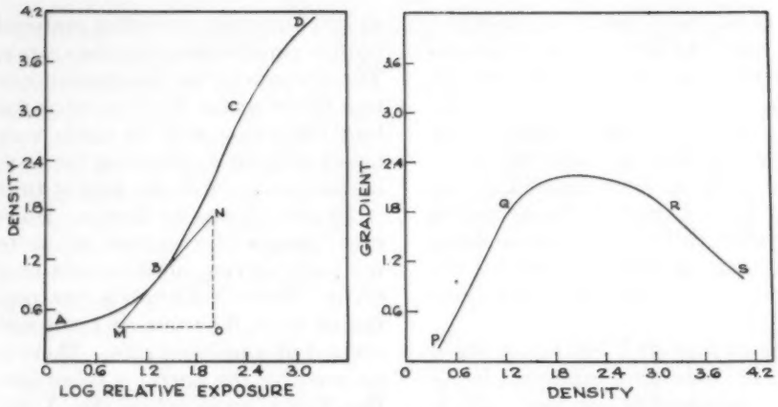

Fig. 7.—Typical Characteristic Curve (left) and Its Gradient Curve (right).

for use as an example simply to illustrate the principles involved.

The characteristic curve of a photographic material is sometimes called the *H* and *D* curve after Hurter and Driffield who, in 1890, first used a plot of density *versus* log exposure for the scientific study of photographic emulsions. The *logarithm* of exposure is taken rather than the quantity itself, partly because it compresses a long linear scale, and also because analysis of the curve is thereby simplified. If different times of exposure are used to obtain the data for this curve, it will be convenient to choose values such as 1, 2, 4, 8, 16. . .seconds or minutes since their logarithms occur at *equal* intervals on the log exposure scale. The logarithms of this series are approximately 0, 0.3, 0.6, 0.9, 1.2. . ., respectively. Note that one exposure *divided by* the one immediately preceding it is 2.0, while the *difference* between succeeding logarithms is always 0.3. The exposure series 1, $\sqrt{2}$, 2, $2\sqrt{2}$, 4, . . .is represented by the logarithms 0, 0.15, 0.3, 0.45, 0.6, . . .and could be used if more data were desired, for the sake of determining the curve with greater accuracy. Here, the *ratio* is $\sqrt{2}$ and the constant difference of the logarithms is 0.15. It is apparent then that anywhere on the characteristic curve a certain *percentage* increase of one exposure over another is represented by the same difference between the logarithms of the two exposures.

The region *AB* is called the *toe* of the curve and is relatively unimportant radiographically because large changes in X-ray or gamma-ray intensity are necessary to yield appreciable density differences. Thus, a steeper curve is more desirable. The region *BC* is much steeper than the toe and radiographs made in this density range are said to have higher "contrast" than if made in the toe region.

A quantitative measure of film contrast is given by the "slope" or steepness of a straight line such as *MN*. The slope of *MN* is obtained by dividing the length of *ON* in density units by the length of *MO* in log exposure units. In photographic work, it is called the "gradient," *G*. As *MN* is moved along the curve, the gradient changes, being small in the interval *AB*, nearly constant from *B* to *C* and decreasing from *C* to *D*. If the gradient has a large average value over the range *BC*, the film is said to have high contrast. Most common photographic negative materials, when exposed to light, show a well-defined straight-line portion between *B* and *C*. The slope of this straight line is called "gamma" but, since the curves for X-ray films seldom straighten out for an appreciable interval and often continue to increase in slope above the range of usable densities, they have no significant gamma. For practical purposes, the slope of the straight line joining two points at the limits of the most useful part of the curve is a good measure of film contrast and is called "average gradient." The gradient begins to diminish in section *CD*, the "shoulder," so that detail begins to disappear, no matter how much light is available to penetrate these high densities. For most industrial direct-exposure X-ray films, the shoulder starts at densities that are too high to be utilized in practice. The maximum brightness of the illuminator then becomes the factor which limits the usefulness of the high density region.

The curve *PQRS* in Fig. 7 is a plot of gradient values *versus* density obtained from the characteristic curve *ABCD*. The procedure consists in drawing triangles, such as *MNO*, at enough different densities so that when the slopes of the *MN*'s are plotted against densities a smooth curve is obtained. Since the gradient for this particular film is a maximum at $D = 2.2$, the radiographic technique should be adjusted so that the most important features of the specimen are rendered at or near this density. In this way, details which are of the most interest will be recorded with the greatest possible *density differences* or contrast. However, if the illuminator is not sufficiently bright, lower densities at correspondingly lower contrasts must be used. Gradient values are a measure of the ability of a film to show detail, assuming constant conditions of film graininess and focal-spot geometry.

There are several ways in which gradient and characteristic curves can be of real help in radiography.

Example 1:

Let a radiograph be made using the film illustrated in Fig. 7. Assume that the penetrameter contrast turns out to be 0.03 at a density of 1.0, that is, the density difference between the penetrameter image and its surroundings is 0.03 where the density is 1.0. From the curve we see that the film gradient is 1.2 at a density of 1.0. If the exposure is increased so as to give a density of 1.8, what will the penetrameter contrast be? The gradient at $D = 1.8$ is 2.2. Therefore, the penetrameter contrast will be given by $\frac{2.2}{1.2} \times 0.03 = 0.055$. Since the *density difference* is nearly double its former value, the penetrameter image will be noticeably more prominent.

Example 2:

Suppose a radiograph obtained with film *x*, Fig. 8, from a trial exposure of a certain casting, has a density of 0.8 in the area of greatest importance. And suppose the exposure was 12 ma-min. The details are not shown as well as they would be at a higher density because of the greater contrast there available. It is

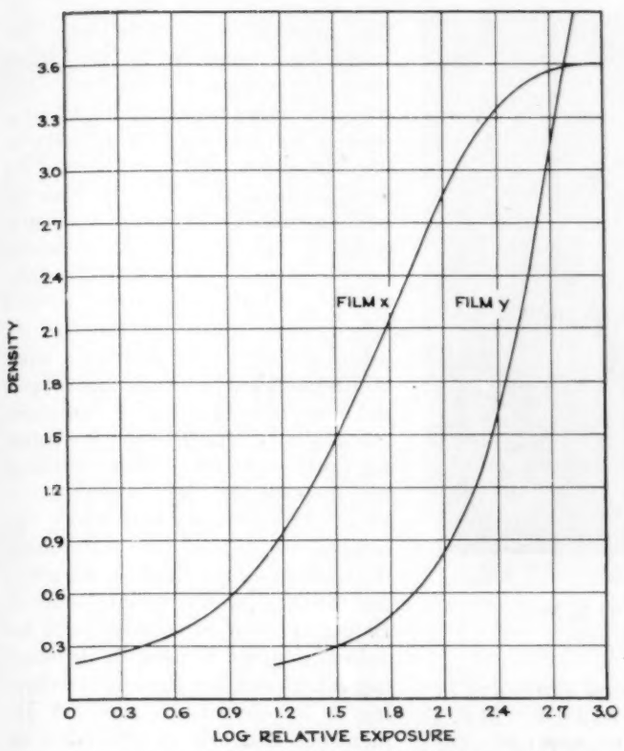

Fig. 8.—Typical Characteristic Curves of Two Films Exposed to Direct X-rays.

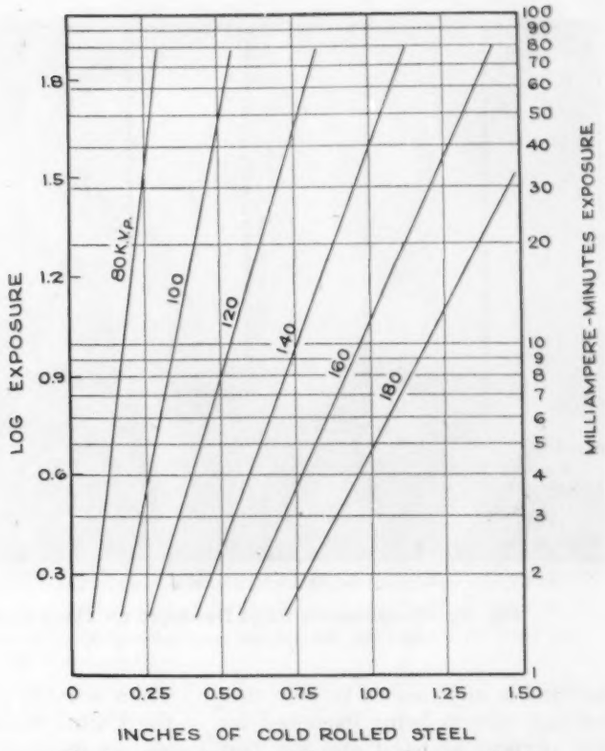

Fig. 9.—Typical Form of Exposure Chart for Steel.
For practical use, the distance, type of film and processing would be specified.

apparent that the maximum gradient (greatest steepness) of fiim x occurs at about $D = 2.0$. What increase in exposure is necessary in order that the area considered shall have this density?

log E at $D = 2.0$ is 1.7
log E at $D = 0.8$ is 1.1
Difference in log E is 0.6
Antilog of the difference is 4.0

Therefore, the first exposure should be multiplied by 4.0, giving 48 ma-min.

Example 3:

Film y has higher contrast at $D = 2.0$ than film x but is "slower," that is, a longer exposure is required to produce the same density. If the radiograph in the preceding example is to be made on film y at a density of 2.0 instead of on film x at a density of 2.0, what exposure change is required?

log E at $D = 2.0$ for film y is 2.5
log E at $D = 2.0$ for film x is 1.7
Difference in log E is 0.8
Antilog of the difference is 6.3

Therefore, the exposure for film x should be multiplied by 6.3, giving 300 ma-min., the exposure for film y.[3] It will be noticed that the log E interval between these two curves depends upon the density at which it is measured. Therefore, the percentage change in exposure to go from film x to film y will depend upon the density. If the two curves were identical in shape, the exposure adjustment would be independent of the density and the contrasts at the same density would be equal.

Film y continues to increase in contrast above a density of 2.0. High densities require bright illuminators but the point is finally reached at which no practical device can supply enough light *through the radiograph* to enable the eye to appreciate the high contrast present.

Example 4:

According to the exposure chart, Fig. 9, 35 ma-min. are required to produce a density of 1.0 through 1.5-in. steel at 180 kv. If this is the maximum thickness of steel in the specimen, the minimum density in the radiograph will be 1.0. The question naturally arises as to what density will occur in parts of the image corresponding to thinner parts of the specimen. Take, for example, a part 1 in. thick. It will be given the same exposure (35 ma-min.) as the rest of the radiograph but, according to the chart, requires only 5 ma-min. for a density of 1.0. Log 35 ma-min. minus log 5 ma-min. is the log relative exposure for the two thicknesses (1.5 − 0.7 = 0.8). Referring to the characteristic curve for film x in Fig. 8, it is found that this increase in log E beyond 1.2, the log E for a density of 1.0, gives 2.0, the log E for a density of 2.7. This, then, will be the density in the radiograph for the 1-in. part of the specimen. It is thus possible to calculate the approximate density range to be expected in a radiograph and thereby to adjust the technique to keep within the limits set by the illuminator.

Factors Influencing the Shape of the Characteristic Curve

The foregoing paragraphs show how the characteristic curve is used to determine the contrast and relative speed characteristics of X-ray film as well as to enable one to calculate densities to be expected when techniques are changed. Thus, the characteristic curve may properly be considered as a *calibration* of the film. Several variables, however, may affect the shape of this curve and it is therefore necessary to use great care in order that certain conditions shall be the same for preparation of both the sensitometric and the radiographic films. It is, of course, for the sake of maximum accuracy that rigid control is maintained over all variables, particularly in radiographic research. The use of published curves is permissible only where rough approximations are adequate. Good judgment derived from experience must be

[3] From a practical standpoint, an increase in kilovoltage would be in order for the exposure on film y to avoid unreasonable exposure times. This is calculated from an exposure chart, not from the film characteristic.

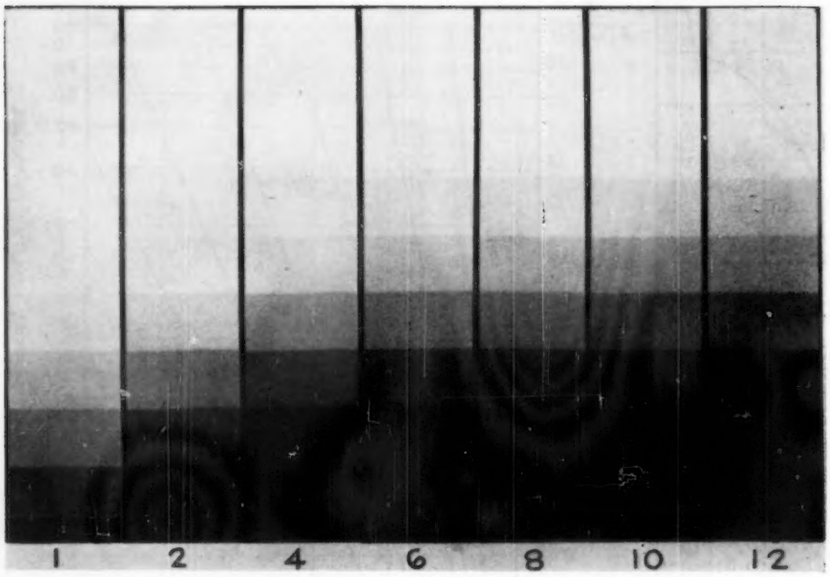

Fig. 10.—Sensitometric Strips Developed for Times from 1 to 12 Min.
All strips received the same series of X-ray exposures.

applied in any case to be sure that enough care is being exercised for the purpose at hand and yet that effort is not being wasted in obtaining high accuracy when a mere estimate is sufficient. For great accuracy, sensitometric or calibration exposures (for the characteristic curve) and radiographs should be processed *together* but *fair* accuracy may be attained if conditions are duplicated as well as possible without necessarily processing all of the films simultaneously.

Figures 10 and 11 show the effect of time of development. If the time is too short, the contrast as well as the speed will be low; if the time is too long, development fog may be great enough to reduce contrast, and the increase in density will give a false impression of speed. The manufacturer can make recommendations for a good average time of development as well as the time for maximum speed and contrast.

The activity of a developer is very sensitive to changes in temperature. Development is completed in a much shorter time at high than at low temperatures. This is, of course, true of most chemical reactions. If the developer temperature is a little higher or lower than normal, a different time may be used as compensation. The exact amount of the change is found in the time-temperature schedule for the kind of developer and film in use. There is fairly general agreement in the United States on 68 F. (20 C.) as a standard temperature for photographic processing.

As films are developed, the active ingredients in the developer are used up and reaction products accumulate. There is also a gradual but appreciable loss of developer because some clings to the films when they are removed from the tank. It is therefore necessary to adopt a system for renewing the activity of the developer and maintaining its level in the tank. If this is done by adding fresh developer of the same kind, it will, in general, be necessary to increase the time of development according to some tested schedule to make up for the inadequate revival of activity. Special replenisher solutions have been devised, however, which maintain the original strength of the developer for quite some time, thus requiring no increase in the development time. The accuracy with which the original conditions are maintained depends to some extent on the average density of the general run of radiographs for, obviously, more developing agent is used in developing a high-density than in developing a low-density image. A replenisher must be compounded on the assumption that radiographs of average density prevail, but if this is not the case, proper allowance can be made by changing the rate of addition of the replenisher.

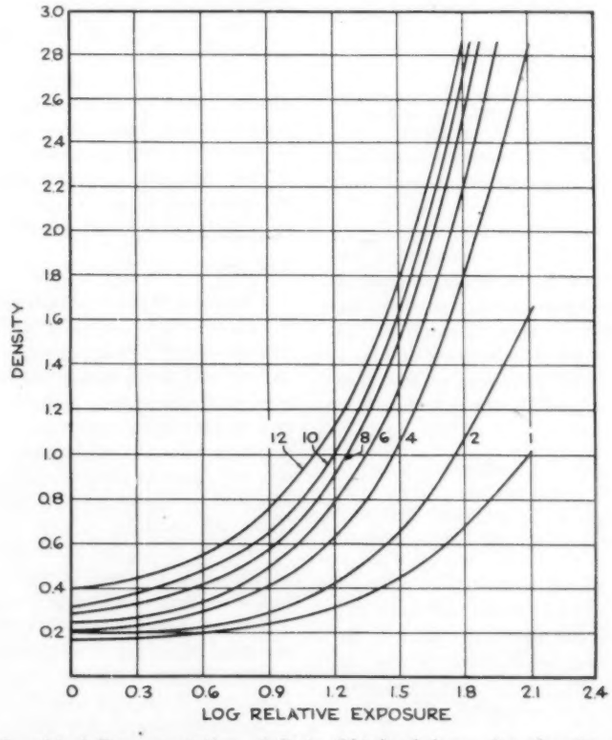

Fig. 11.—Graphical Representation of Data Obtained from the Sensitometric Strips Shown in Fig. 10.

Note the trend toward low contrast in the toe of the 12-min. curve caused by high fog associated with excessive development.

Another important factor in the duplication of developing conditions is the amount of agitation. If an exposed film is carefully immersed in a tank of developer which has been undisturbed for some time and the film is permitted to develop under quiescent conditions, streaks may appear on the finished radiograph. These streaks will be especially noticeable if high- and low-density areas are adjacent. The effect is caused by the restraining action of the decomposition products which tend to flow down the film. Continuous, but *not* rapid, movement of the film during development will keep the solutions mixing. This procedure should be followed carefully where accurate measurements are to be made, but a few seconds of agitation every minute or so meets the requirements of routine processing. Horizontal movement of the film, or a slight amount of rotation about a vertical axis is preferable to vertical motion, but local conditions, such as crowded tanks, may make this impractical and vertical motion must then suffice. Since agitation promotes contact between the film and fresh portions of the solution, it increases the rate of development as compared with stationary development.

In addition to the care exercised in duplicating processing conditions for sensitometric and radiographic films, some attention must be given to the radiation used. Experiments on a limited number of different types of X-ray films have shown that the *shape* of the characteristic curve is only slightly affected by changes in kilovoltage, when enough metal is used in the path of the rays to simulate radiographic conditions. The position of curves made at 60 and 80 kv., for example, with the same film, would be at different *locations* along the exposure axis since X-ray intensity depends to a marked degree on tube kilovoltage, but probably no difference in *shape* would be noticed. Thus, a sensitometric curve made at 80 kv. might well serve for work done in the 50- to 100-kv. range, but tests should be made to make sure that, for a given kind of film, no change in curve shape is noticeable for the qualities of radiation being used. It must be kept in mind that the shape of different characteristic curves implies nothing whatever about the relative spectral response of the films. The characteristic curve is strictly a density-exposure relationship and does not indicate anything about wave length response.

When lead foil screens are used with hard radiation, a considerable part of the exposure is produced by the electrons emitted. It is not surprising, therefore, that the characteristic curves of some films obtained with lead screens are a little different from those found when the entire exposure is made with X-rays. Since the degree of intensification of lead screens depends on the quality of the radiation used, the change they effect in the characteristic curve will also depend on the quality of the radiation. Therefore the limits of applicability of a characteristic curve must be known if accuracy is desired.

When calcium tungstate intensifying screens are used with screen-type film, almost the entire exposure is due to their light. Since the color of the light seems to be independent of the quality of radiation which excites it, the curve obtained with screen light should not be affected by changes in kilovoltage. Reciprocity-law failure is associated with light exposures, and it may be necessary to make a correction for this or to make the characteristic curve on an *intensity scale* for about the same *length of time* as the experimental radiographs.

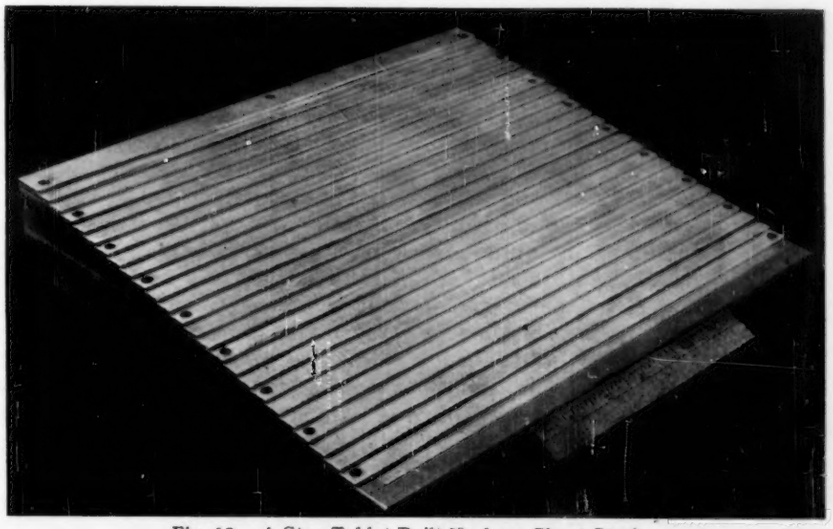

Fig. 12.—A Step Tablet Built Up from Sheet Stock.

Application of Step Tablets to the Study of Film Properties

A "step tablet" or "stepped wedge" consists of a block of material, one face of which is in the form of a stairway (see Fig. 12). If such a step tablet is radiographed, the film will receive a graded series of exposures corresponding to high intensities at the thin end of the tablet and low intensities at the thick end. Assuming that all of the 'risers" are equal, consecutive steps at the thin end of the tablet produce a greater percentage change in intensity than at the thick end because of the difference in filtering of the rays. This is further accentuated by the greater scattering in the thicker parts. If each step caused the *same* percentage change in intensity, the log E difference would be the same throughout and it would be convenient to plot density *versus* log E as in Figs. 7 and 8. It is possible to adjust step thicknesses to make these log E intervals equal but it is hardly worth while for the purpose at hand.[4]

Before discussing details of procedure, it is well to consider suitable dimensions for a step tablet. The tablet should cover a greater area than actually needed so that the

[4] A step tablet giving equal log-exposure intervals throughout its length has been constructed in the Kodak Research Laboratories. It was built up principally from laminations of steel 0.010 in. thick. Final adjustment of absorption of the thinner steps was accomplished with thin aluminum since steel sufficiently thin for this purpose is mechanically unsuitable. The X-ray intensity increase per step was 26 per cent or a log E interval of 0.10 at 80 kvp.

region near the edges, where a large variation in scattering occurs, can be neglected. A tablet measuring 9 by 11 in. is a convenient size. It probably would give reliable results to within 1 in. of the edge of an 8 by 10-in. film. Tests should be made on a tablet to determine the extent of this scattering variation. A tablet made up of rolled aluminum sheets $\frac{1}{16}$ in. thick showed an average intensity change per step of about 25 per cent (log E about 0.1) in the middle when radiographed at 80 kv. Steps $\frac{1}{16}$ in. thick in cold-rolled steel gave an intensity change of about 35 per cent per step when radiographed at 180 kv. At 1000 kv., $\frac{1}{4}$-in. steps in cold-rolled steel gave a 35 per cent intensity change, using the beam transmitted by the target. These examples are given for illustration and are approximate values only. Other approximations may be obtained from exposure charts (see Fig. 9) in which it is customary to plot exposure on a logarithmic scale for various kilovoltages *versus* metal thickness. Since the step value in terms of intensity depends on kilovoltage, it will depend on radiation quality in general and therefore upon the voltage wave form of the particular X-ray machine used. A step tablet can only be used reliably when calibrated for a given set of conditions on a particular machine.

One obvious procedure for calibrating a step tablet is to radiograph it and interpret the various photographic densities as X-ray intensities by referring to the characteristic curve of the film used. However, a certain amount of apparatus is necessary to obtain data for the characteristic curve and this may not always be available. A "cut-and-try" method must then suffice.

Several radiographs of the tablet are made for different *known times* of exposure. These are all processed together with the low-density ends of the films up in the developer to minimize streaking. Occasional agitation also promotes uniform development. For the sake of illustration, it is assumed that one radiograph is exposed for 1 min. and another for 2 min. When viewed on an illuminator, it is found that an approximate density match is obtained by shifting one radiograph four steps past the other. The logarithm of the intensity change per step is therefore $\frac{0.3}{4}$ or 0.075. (The value 0.3 is the logarithm of 2, the exposure ratio, and 4 is the number of steps difference.) The antilog of 0.075 is 1.19; therefore, the intensity increase per step of decreasing thickness is 19 per cent. On almost any tablet, it will be found that intensity intervals near the thick end will be less and near the thin end greater than the average value. The most useful part of the tablet is in the middle region, but tests should be made to determine the practical limits by comparing the step differences *at different places* for a given ratio of exposures. In the example cited, the correctness of the result may be checked by making two radiographs of the tablet, one being 19 per cent greater in exposure than the other. Exact agreement should be obtained just one step apart.

Once a step tablet calibration has been established by repeated tests and the X-ray machine is known to be reliable in repeating the same radiation quality for the same settings, the tablet may be used for comparing X-ray films, if desired. Strips of the various films are placed, side by side, in a suitable holder and given the standard exposure through the tablet. The time of exposure may be adjusted within reasonable limits to correspond to the speed class of the films. The strips should be processed together and every effort made to insure similar treatment. The speed relation of the films is found by noting the number of steps one is moved with respect to another in order to obtain a density match. Fractions of a step are estimated. By way of illustration, assume that film A is *three steps* faster than film B on a 20 per cent tablet, that is, a tablet for which the X-rays are 20 per cent more intense through a given step than through the adjacent thicker step, at the specified kilovoltage. Let the speed of the slower film be called 100. The faster film speed is *not* 3×20 per cent or 60 per cent greater; instead the speed ratio is given by the antilog of (3×0.079) times 100. (The antilog of 0.079 is 1.20 and of 3×0.079 is 1.72.) Thus film A has a relative speed of 172.

Films A and B may also be compared in contrast by means of the step-tablet exposures, but there is some risk of misinterpretation if the strips must be moved several steps to obtain a density match at some point. The reason for this is that a considerable range of the tablet may be required to make the contrast difference plain and there is then the temptation to utilize the ends where the step percentage deviates from the average in the middle. A more reliable method is to make the speed test first and then to expose additional samples separately, compensating for the difference in speed by adjusting the exposure times so that the films will appear to be exactly equal in speed. If a difference in contrast exists, it will be apparent because the films will match in density on only one step, the film of higher contrast having higher densities at the high-density end and lower densities at the low-density end.

Fog

A small part of the density appearing in a radiograph develops from grains which were not affected by the exposure, but which have been reduced to metallic silver by the developer. The density thus produced is called *fog*. A film with excessive fog will be rated higher in speed than if it had a normal amount of fog, unless a correction is made. A proper correction is complicated by the fact that more fog exists in the lower densities than in the higher densities of the radiograph. This fact seems reasonable because the more grains there are affected by exposure, the fewer there are remaining to supply fog grains. Most practical purposes are served by simply subtracting from the image densities the density obtained on an unexposed processed film. A strip of unexposed film processed for determining fog is commonly referred to as a *fog strip*.

When the step-tablet method is used for estimating relative film speeds, a densitometer is not ordinarily used, so that the exact influence of fog on the comparison will not be known. To compensate for the effect of fog, unexposed films are processed with those exposed

through the step tablet, and during viewing the fog strip for film *A* is placed over film *B* and the fog strip for film *B* is placed over film *A*. Thus, both films are made to have apparently the same total fog. The advantage of this procedure is its simplicity. It is *equivalent* to subtracting a constant fog density from the various image densities.

Because fog is greater in the lower densities of the image, it reduces film contrast (see Fig. 11). It is apparent that the slope or steepness of the 12-min. curve is less than that of the 10-min. curve. If fog were the same over an entire radiograph, it would be equivalent to adding the same density to *all* parts of the 10-min. curve, which would not change the slope and would therefore not affect the contrast. Thus, viewing a radiograph or a test strip through an additional film of uniform density, such as a fog strip, does not alter the contrast because it does not change the density *differences* in the image. If the added density is high, some detail in the radiograph may be lost because of the lesser amount of light reaching the eye, but this is a *subjective* effect. The original clarity of detail will be restored by increasing the illuminator brightness to make up for the light absorbed by the uniform density. It is apparent then that the development of fog in a radiograph cannot be accurately simulated by viewing a fog-free radiograph through a uniformly developed fog strip.

Graininess

The principal characteristics of a radiographic film which determine its effectiveness in showing detail are contrast and graininess. (If intensifying screens are used, their graininess is more important than that of the film itself.) One of the quantitative concepts of contrast, namely, gradient, was discussed above under "Interpretation of the Characteristic Curve." It must be emphasized that there are other factors in the radiographic process which affect the quality of a radiograph, such as the geometry of the setup, secondary radiation, and the kilovoltage used. These, however, are not related to film properties.

The individual particles, or grains, of silver, which form the radiographic image, require a magnification of several hundred diameters to be seen. Upon close visual examination, however, radiographs made on most types of X-ray films exhibit a somewhat grainy structure caused by the more or less irregular grouping of the silver grains into clumps. This appearance is called "graininess." On the very fine-grain X-ray films, magnification of a few diameters may be required to see the graininess. Although the general tendency is for emulsions made with large individual grains to show the greater graininess, from the standpoint of the user of X-ray film, *graininess* rather than *grain size* is the matter of most concern. Films vary in their graininess and, in general, those with the least grainy appearance are slowest in speed. This is a good reason for choosing the slowest film, consistent with other requirements, for a given application.

It is common experience that a given film shows increasing graininess, the harder the X-radiation used in the exposure. Thus, increasing both kilovoltage and filtration causes more graininess, though a large change in either is usually necessary to make a significant difference. Although this is a well-established phenomenon, it is by no means clearly understood. Its practical significance, however, is illustrated by the tendency of operators to stress the use of fine-grain films for high-voltage radiography. If samples of several different types of film which have been exposed at low voltage are compared and a similar set compared after exposure to high voltage, heavily filtered radiation, their *relative* graininess may or may not be the same. *Each type* will be found to be more grainy because of the higher-voltage exposure, but it does not necessarily follow that all will have increased in graininess at the same rate. Thus, test exposures made for graininess comparisons should all be made with radiation of approximately the same quality as that used in practice. Because of the need for equal brightness of areas being compared, it is important that films be judged for graininess only if their densities are equal.

Limited tests have shown that when lead-foil screens are used with radiation hard enough to give considerable intensification, the image is *slightly* more grainy than for the direct X-ray exposure. The difference is certainly not great enough to begin to offset the advantages of lead foil in removing secondary radiation and in intensifying the image. It is hard to imagine any technique in which the small increase in graininess from the use of lead screens would be of practical importance.

When X-ray films are exposed with light, the graininess is materially less than when exposed with X-rays. An apparent exception to this is that an exposure with calcium tungstate intensifying screens, in which their fluorescent light constitutes 90 per cent or more of the exposure, shows more graininess than a direct X-ray exposure. The reason is that the screens themselves have a granular structure and, since the screens are in good contact with the film, this structure is recorded by the film. (Screen graininess, like film graininess, seems to increase with kilovoltage.) If the screens are held only a fraction of an inch away from the film, a remarkably smooth appearance of the silver deposit results, but this procedure is out of the question in practice, since image outlines would be blurred out. We can see from the test, however, that light produces a relatively fine-grained image and that the graininess of radiographs made with tungstate screens is due principally to the screen pattern.

Much has been written in the field of photography about the effect of various developers and developing methods in reducing graininess, and some of it is quite controversial. Dilution of a developer has been found effective in lessening graininess but, for the same time of development, contrast also is reduced. Thus, some sacrifice is made in one desirable characteristic to attain benefit in another. In general, a developer of low activity tends to produce finer-grained images than one of high activity. In the case of some X-ray films, there is greater graininess in a film which is developed to maximum contrast, by using time as the variable, than in one developed to moderate

contrast. It is probable that this difference is primarily a contrast effect. At any rate, the difference is too small to be given serious consideration, particularly because of the sacrifice in speed and contrast associated with shorter development times.

Processing

It has already been pointed out that the developer reacts with the silver-salt crystals which have been affected by the exposure, reducing them to metallic silver, but changes very few of the unaffected crystals. The developer solution is a complicated mixture because there seems to be no one chemical which is entirely satisfactory when used alone. Developing agents, such as elon or hydroquinone, need to be used with an alkaline salt to increase their activity. Oxidation of the developer is retarded by the addition of sodium sulfite. Potassium bromide is found essential in most formulas to restrain fog.

The various factors which determine the degree of development, namely, time, temperature, amount of agitation, and the activity of the developer, were discussed under the heading "Factors Influencing the Shape of the Characteristic Curve." Some of the details of darkroom work will now be considered.

There is no single element in radiographic work more deserving of attention than cleanliness. Proper design of the darkroom will facilitate attainment of this goal. One side of the darkroom should be equipped with a bench on which film is unpacked, cassettes and hangers are loaded, and general "dry work" done. All processing equipment and sinks should be on the opposite side of the room. This arrangement greatly reduces the tendency to contaminate the loading bench, films and screens with chemicals. Powdered chemicals should not be mixed in the darkroom because some will inevitably settle on the loading bench and be picked up by films. In many industrial plants it is difficult to keep cassettes free from grit and dirt, but a special effort should be made to control it. A compressed air hose may be useful in cleaning cassettes if the air itself is not contaminated with oil or other impurity from the compressor. (Do not clean them in the darkroom!) Possible sources of trouble from dirt will vary, depending on the circumstances, and it is futile to attempt an analysis based on hypothetical conditions. It is up to the operator to be vigilant, realizing that he is dealing with materials which are sensitive to other chemicals, gas fumes, and even fingerprints from "clean" hands.

It has been pointed out that agitation of films during development reduces streaking. A further contribution to uniformity is made by thoroughly rinsing the films in clean water after development. This is not as effective, however, as occasional agitation of the developed film in an acid stop bath for a half minute or so. The acid treatment neutralizes the alkaline developer and is therefore much more effective in arresting development than plain water. It also prolongs the acidity of the fixing bath which would be more or less neutralized by traces of developer still left in the film after an ordinary water rinse. The stop bath should not be used beyond exhaustion as this induces stains or spots. Its chemical composition should be suited to the developer with which it is used. A test for acidity should be made and the bath discarded when it is too weak to be effective.

From the stop bath the films are immersed in the fixing bath. Sodium thiosulfate ("hypo") or ammonium thiosulfate is the ingredient which dissolves out the undeveloped silver salts. The time for fixation should be extended well beyond that required for clearing in order to permit the dissolved silver salts to diffuse out of the emulsion. Although removal of the undeveloped grains is the principal function of the fixing bath, it is important that it should contain an acid, for example, acetic acid, to insure complete neutralization of traces of alkaline developer and to facilitate hardening of the gelatin. Sodium sulfite is a preservative which keeps the hypo from being decomposed by the acid. A hardener, such as potassium alum, keeps the gelatin of the emulsion from swelling too much or becoming soft in the wash water. This agent is of most value in the summer when the wash water may be warm.

If the films were merely rinsed after being in the fixing bath, they would still retain enough chemicals to cause fading and discoloration when kept for any length of time. Thorough washing in clean, running water is essential for the production of satisfactory radiographs. Washing is most effective and economical of water when using the cascade system, that is, the washing compartment is divided into two parts and the water flows from one to the other and then out at the drain. Films are washed first in the tank nearer the drain for about half the washing time and then moved to the inlet tank. As this process continues, the films just out of the fixing solution are washed in slightly contaminated water coming from the tank in which the films are practically clean. The net diffusion of concentrated chemicals from the emulsion into slightly contaminated water is rapid at first, but slows down as the concentration in the emulsion approaches that in the water. If the film is transferred to clean water, diffusion proceeds to completion. The objection to single-tank washing systems, therefore, is the fact that films heavily loaded with hypo interfere with the final washing of those already in the tank, and it is necessary to leave *all* of the films in the tank until those last added are clean. No film will become cleaner than the water in which it is finally washed!

Washing tanks should be so designed that the water flows completely over the tops of the film hangers. This prevents subsequent contamination of developer with hypo which might otherwise dry on the hanger bar. Hanger clips should be cleaned occasionally since water cannot circulate sufficiently through the contact faces of clips for thorough cleaning.

Films are left on their hangers to dry and may be hung up out of the way in a room where ordinary atmospheric conditions prevail, if the air is reasonably free from dust. Drying cabinets are on the market which furnish a flow of warm, filtered air and these naturally provide a shorter drying time than the average room. Care should be

taken that the air is not warm enough to soften the emulsion. Its velocity of flow should not be great enough to blow water drops off one hanger onto an adjacent film.

Immersing the film after washing in a bath of water-spot-preventive lessens the incidence of drying marks. This bath is a very dilute solution of a chemical which reduces surface tension, thereby causing the water to drain off evenly without leaving large drops. Total drying time is lessened, not because the film area itself dries so much faster, but because there are no large clinging droplets.

It should be a routine matter to trim the corners of radiographs as soon as they have been removed from the hangers. The projections of film caused by the puncturing points of clips are very sharp and can easily scratch other radiographs with which they come in contact.

Because of the various makes and types of radiographic materials on the market, the author has attempted to present only the most general principles, leaving detailed recommendations to the various manufacturers.

Dimensional Stability of Plastics

By Robert Burns[1]

SYNOPSIS

Because of inherent insulating properties, rigid plastics play an important part in the design and manufacture of precision electrical apparatus. Almost invariably, practical design considerations require that the plastics have reasonable structural possibilities since it is rarely practicable to disassociate completely electrical and structural functions.

This paper discusses one of the important factors in the successful use of plastics in precision devices, namely, dimensional stability. Since plastics are organic compounds, one must be prepared to accept a degree of instability not usually encountered in metals. The measurement of this property is therefore of prime importance to the user of plastics since the data provide a basis for design adjustment which frequently is the difference between failure and success.

The various types of dimensional change are reviewed. Data illustrating the separate effects of humidity, drying, and cycling procedures are submitted. The influence of fabricating processes such as compression or injection molding, and sheeting, is included.

TYPES OF DIMENSIONAL CHANGE

THE discussions herein are confined to what might be termed zero-stress conditions, that is, where no external stresses such as compression, tension, etc., are applied. They therefore exclude deformation under load, heat distortion, and similar procedures where elastic or plastic flow results from externally applied stresses. In any engineering consideration of zero-stress dimensional change it should, of course, be remembered that such changes can occur simultaneously with those produced by externally applied stresses. Zero stress dimensional change may also oppose the changes caused by externally applied stresses. For example, oriented sheet may grow thicker rather than thinner under low external pressure. Cold flow values at moderate external pressures also will vary with the degree of molded stress in the sample.

Plastic parts, or test specimens, change in dimensions because they are inherently unstable, or are made so by manufacturing processes, or both. It is very important to keep in mind that all plastics, regardless of chemical composition, are potentially unstable dimensionally because it is virtually impossible to mold or form a part without introducing internal stress. In practice most commercial moldings, espe-

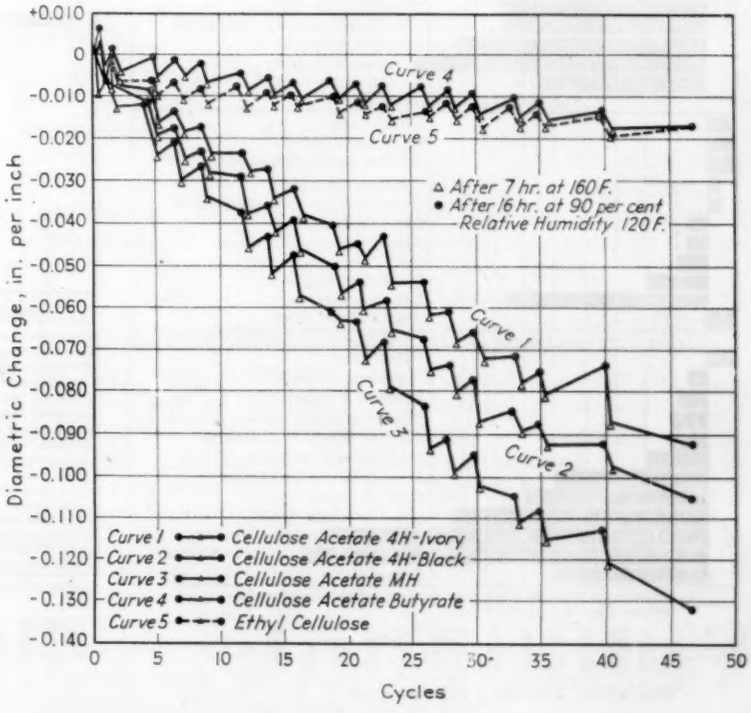

Fig. 1.—Diametric Change.

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[1] Bell Telephone Laboratories, Inc., New York, N. Y.

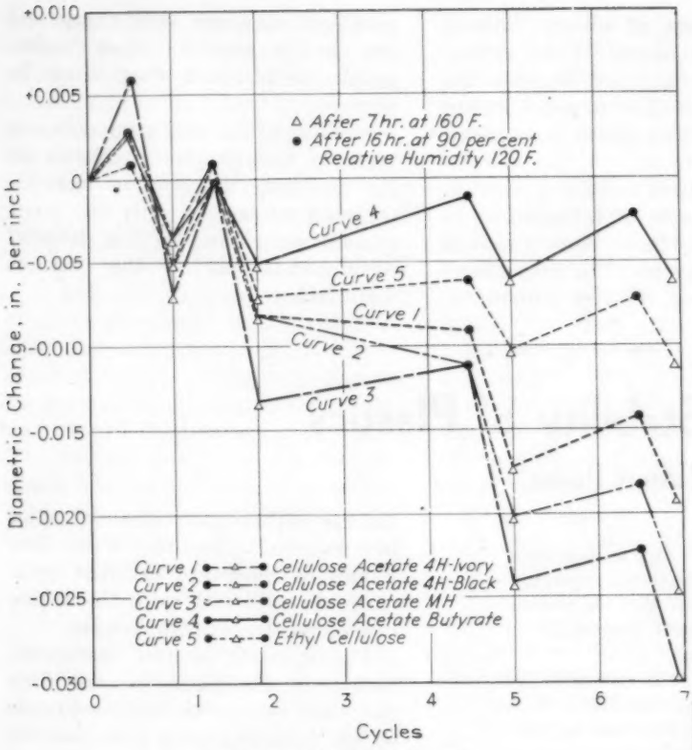

Fig. 2.—Diametric Change.
Expansion of First Seven Cycles of Fig. 1. (7 Cycles = 1 week.)

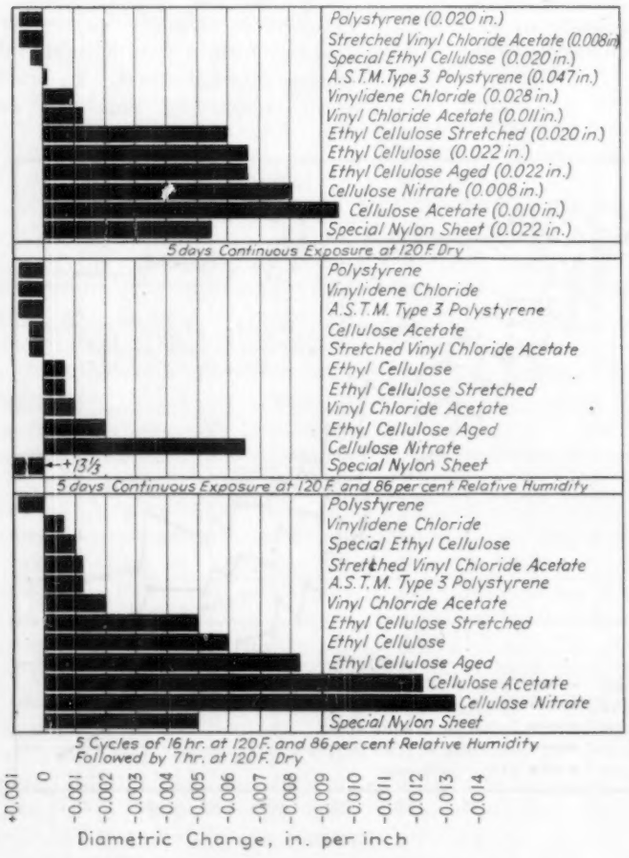

Fig. 3.—Diametric Change of Plastic Sheeting.

cially those produced by the injection process, are highly stressed. On the other hand, the situation is not reversible as even ideal molding conditions will not produce a stable part from an unstable material.

Inherently stable plastics can be defined as those which are not affected by atmospheric influences such as heat, moisture, or combinations thereof encountered in normal engineering use. Unstable plastics, of course, are those which are affected. As pointed out above, stable materials are frequently made unstable by internal molding stresses which later relieve themselves.

Methods of Test

In establishing methods of test for dimensional stability, care must be taken that in our zeal for acceleration we do not introduce methods

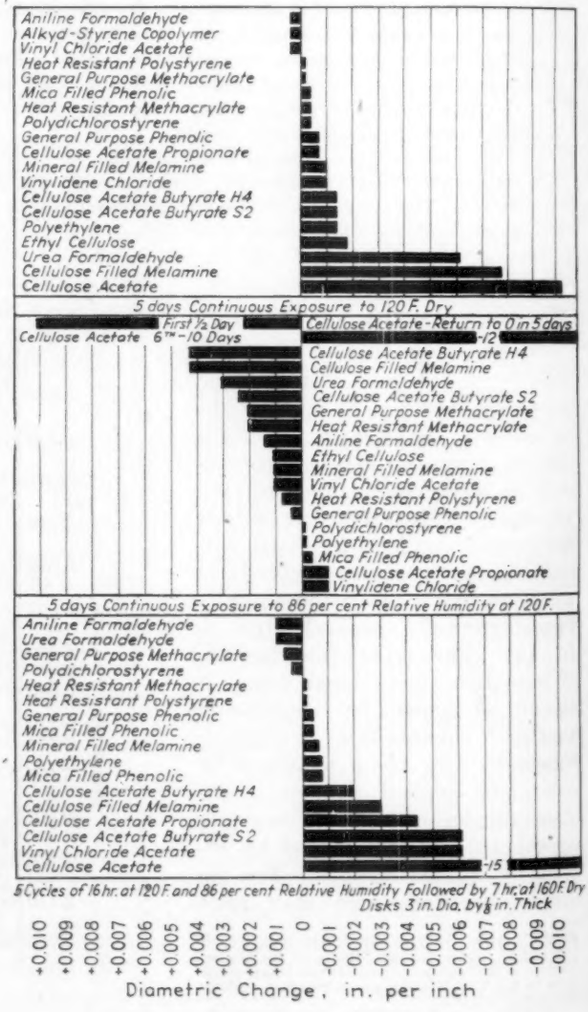

Fig. 4.—Diametric Change of Molded Plastics

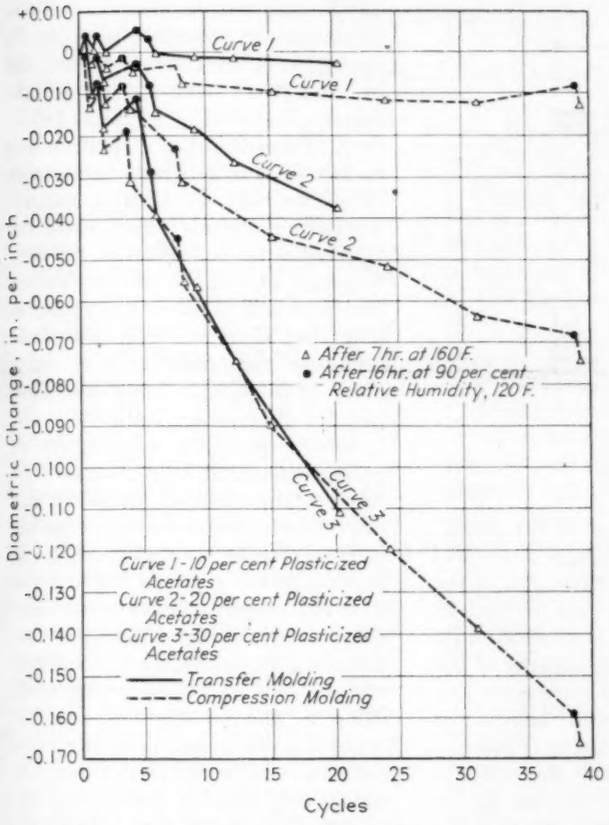

Fig. 5.—Diametric Change of 10, 20, and 30 per cent Plasticized Acetates.

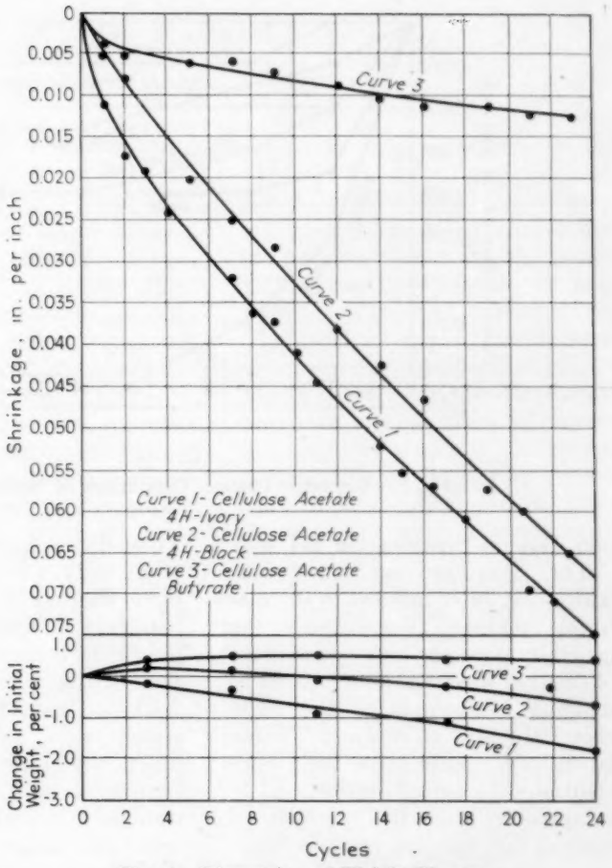

Fig. 6.—Diametric and Weight Changes

which are highly artificial, such as extremely high temperatures, or which apply to only a small part of the product. It is technically and economically unsound to require that all parts meet requirements necessary for the few.

Regarding choice of atmospheric conditions this is purely arbitrary and can be any reasonable state between ordinary room conditions and those which are obviously too severe. In the twenties we introduced the following: 2 days at 90 per cent relative humidity and 85 F. (representing a state of wetness attained during the summer), followed by 2 days at 120 F. (representing a state of dryness attained in a steam-heated room in the winter), or continuous exposure to either.

In 1940 we adopted a more accelerated test as follows: 16 hr. over a potassium nitrate solution, about 86 per cent relative humidity, at 120 F. followed by 7 hr. at 160 F. dry, or continuous exposure to either. Unless otherwise mentioned these conditions, or modifications thereof, are the basis for the data given herein. For example in testing thin sheets, it was desirable to use 120 F. for the drying part of the cycle to avoid the excessive warping which would occur in some materials at the higher temperature. Unless otherwise noted, the molded test specimen is a 3-in. diameter by $\frac{1}{8}$-in. thick disk, compression molded and presumably of low internal stresses. All "dry" measurements were made after cooling to room temperature in a desiccator jar over calcium chloride.

Data and Discussion

In Fig. 1 are shown cycling data on compression molded specimens of several cellulosic compounds. The plasticizer content of the cellulose acetates was approximately 25 per cent, of the butyrate approximately 13 per cent. It will be noted that although the diametric increase due to humidification, and shrinkage due to drying, are somewhat similar for individual cycles in all compounds the downward slope (sometimes called age shrinkage) may vary substantially.

Figure 2 is an expanded view of the first few cycles, giving a more detailed picture of dimensional response of diameter to moisture and drying.

Figure 3 gives data on a variety of plastics in the form of thin sheeting. The specimens were 3-in. diameter disks cut from commercial sheets of undetermined composition. The cycle data are based on diametric measurements made at the end of the drying period.

Figure 4 shows diametric change of compression molded 3-in. diameter by $\frac{1}{8}$-in. thick disks.

Figure 5 illustrates the effects of plasticizer content and method of molding on diameteric change of cellulose acetate.

Figure 6 compares diametric change with weight change.

Figure 7 gives a comparison between the method used in this study and Procedure I of the A.S.T.M. Tentative Methods of Test for Resistance of Plastics to Accelerated Service Conditions (D 756 – 44 T)[2]

[2] 1944 Book of A.S.T.M. Standards, Part III, p. 1663.

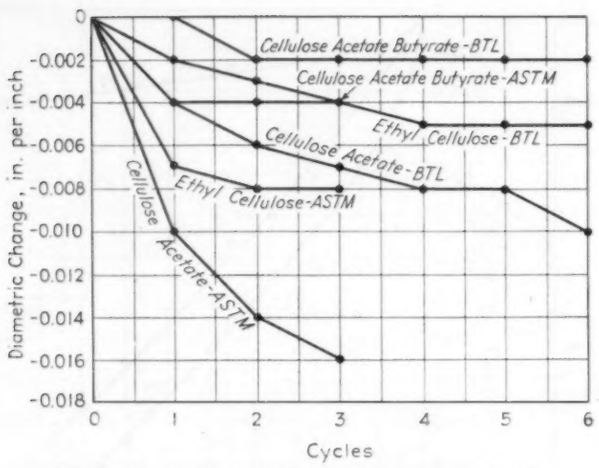

Fig. 7.—Diametric Change, Comparison of Methods.

and Federal Specification L-P-406.

The data provoke discussions which may be of interest to the materials engineer. For example, the generally poor performance of some of the thin sheetings as compared to molding compounds of the same chemical type is striking. These laboratory results have been substantiated by actual experience. It is apparent that the methods of making thin sheeting produce internal stresses which restrict the use of such materials in precision applications.

In the plasticized cellulosic compounds it is common knowledge among technicians that the softer compounds are the less stable dimensionally. The quantitative expression (Fig. 5) of this generalization brings up the question of what actually happens during repeated cycles of humidifying and drying. That it is not due to plasticizer loss is apparent in Fig. 6 where high diametric shrinkage is accompanied by negligible loss of plasticizer.

Further explanation is found in the fact that in many of the compounds the decrease of diameter with repeated cycling is accompanied by an increase in thickness. A few typical data are as follows:

		Thicknesses Before and After 47 Cycles, in.	
		Before	After
Cellulose acetate	Hard	0.127	0.165
	Soft	0.124	0.178
Ethyl cellulose		0.125	0.138
Cellulose acetate butyrate		0.127	0.136

These data suggest a "cold flowing" of the body of the disks as a result of forces exerted by contraction of the periphery. That this is a permanent plastic deformation is illustrated by the fact that thorough drying of the thickened specimens to remove any accumulated moisture results in practically no decrease in thickness. Inasmuch as most dimensional troubles in actual service are due to linear shrinkage, the increase in thickness is usually of little help. The phenomenon of self cold-flowing does not occur in the thermosetting compounds to an appreciable extent.

In choosing atmospheric conditioning procedures for dimensional stability studies, one must differentiate between those which evaluate materials for general use and those which are founded upon some unique service condition. The conditions used for this study are based on the first premise and are on the mild side with respect, for example, to outdoor conditions encountered by the military services. However, the technician must keep in mind that in common with most empirical testing we lose validity rapidly as we hasten results by extreme testing conditions. Speaking generally, it is desirable to qualify materials on data which are discreet and valid, and leave to the apparatus testing procedures the problem of determining performance at very unusual service conditions.

The more recently adopted Procedure I of A.S.T.M. Methods D 756 and Federal Specification L-P-406 is similar to the procedure used herein except somewhat more severe (24 hr. at 140 F. over sodium sulfate solution followed by 24 hr. at 140 F. dry). Procedure I, notwithstanding its severity, is generally acceptable except for very soft or temperature-sensitive materials where excessive warping tends to invalidate the test. A comparison of the two methods is shown on Fig. 7. It is interesting to note that both methods rate these cellulosic materials in the same order of preference from the standpoint of dimensional stability.

In the practical application of plastics one must keep in mind that whereas the effect of humidity and mild elevated temperatures, whether used jointly or severally, is one involving at worst only a few mils per inch (15 would be an extreme case) the effect of the higher temperatures involving stress release is relatively violent. As an example, the vinyl chloride acetate sheeting (Fig. 3) appears to be superior to the ethyl cellulose. However, the sheet materials were dried in the cycling test at 120 F. instead of at 160 F. because the vinyl sheeting became egg-shaped at 160 F., and even at 140 F. The ethyl cellulose remained substantially circular up to temperatures of over 250 F.

It is not the intention of the foregoing to present final engineering data on the materials tested nor to pass on their relative merits for any particular application. It is, however, intended to emphasize that dimensional stability depends on manufacturing processes as well as on materials. The choice of cycling procedures, limiting values of permissible dimensional change, etc., are determined by the particular apparatus in mind, and where it is to be used. In addition, many plastics are available in a wide variety of types permitting the materials engineer substantial latitude.

Acknowledgment:

The author wishes to thank George H. Williams, Anne S. Wrubel, and others of the Laboratories' staff who rendered valuable assistance in this work.

Flexural Properties of Plastics

Summary of Test Results Obtained in Committee D-20[1]

By W. A. Zinzow[2]

THE object of this series of round-robin tests was to determine the effect of various factors on the flexural properties of plastics, prior to the preparation of the A.S.T.M. Tentative Method of Flexural Test of Plastics (D 790 – 44 T).[3] In 1941, Section F of Subcommittee I on Strength Properties of Committee D-20 on Plastics was organized with F. G. Tatnall as chairman of the section. The duty of the section was to present a proposed revision of the flexural strength methods which were in use for various types of plastics at that time. The methods that were in use at that time were those covered by A.S.T.M. Standard Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 39)[4] and Tentative Methods of Testing Molded Materials Used for Electrical Insulation (D 48 – 41 T).[5] It was soon recognized that there were a large number of variables which might affect the results which would be obtained when following these testing procedures. Therefore, the section was organized to determine the effect of these various factors.

Five different laboratories cooperated in making these tests. They were as follows: Monsanto Chemical Co. Laboratory at Springfield, Mass.; Mechanical Engineering Laboratory at Rensselaer Polytechnic Institute; National Vulcanized Fibre Laboratory; Westinghouse Electric and Manufacturing Co. Laboratory; and the Bakelite Corp. Laboratory.

This section set out to determine the effect of the following factors on the flexural properties of the materials being tested. First, the effect of the loading edge radii; second, the effect of the rate of crosshead motion; third, the effect of the span-depth ratio.

From the mass of data reported by these laboratories covering these points an attempt is being made to abstract and present in a summary form some of the pertinent facts which were made available to this section. This is not intended to be a critical analysis of these data but is presented with the thought that members of the subcommittees in Committees D-9 on Electrical Insulating Materials and D-20 involved with these methods would be interested in the information upon which the writing of the Tentative Method D 790 was based.

Effect of Loading Edge Radii

The tests to determine the effect of loading edge radii were made at the Monsanto Laboratories under the direction of H. K. Nason. The following quotation is taken from Nason's report covering this particular point.

"The effect of loading point radii on mechanical tests shows that the radius of the loading points has no measurable effect on the flexural strength or yield point of injection molded cellulose acetate or polystyrene. Figure 41 [accompanying Fig. 1.—Ed.] shows that the variation from one experimental point to another is very similar for the two materials. The effect of loading edge radii by means of photoelastic tests up to a maximum fiber stress of approximately 3000 psi. no differences in the tensile stresses in the lower half of the bars could be detected, see Fig. 52 [accompanying Fig. 2.—Ed.]. The fringe order was about one (in a total of 9) greater just below the 1/64-in. radius molding point than for the 1-in. radius indicating a slightly higher stress concentration for the smaller radius. The difference is small, however, and it is believed that the variation in loading point radii over the range studied produces no serious change in stress distribution. A study of the four-point loading system gave essentially the same results as the three-point system."

From the above report it seems quite reasonable to assume that the radius of the loading edges has very little effect on the results obtained. However, the proposed test method calls for a definite radius of loading

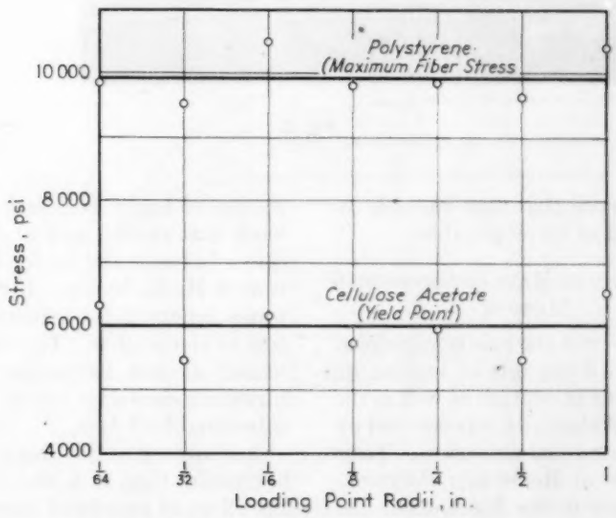

Fig. 1.—Flexural Strength *versus* Loading Point Radii.

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[1] Submitted to Subcommittees II on Molded Insulating Materials and III on Plates, Tubes, and Rods of Committee D-9 on Electrical Insulating Materials and Subcommittee I on Strength Properties of Committee D-20 on Plastics by Section F of Subcommittee I of Committee D-20.

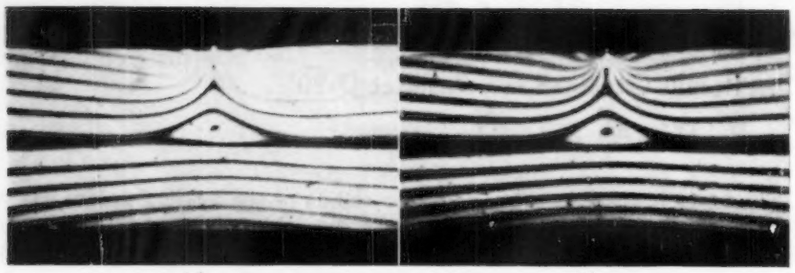
Ed.—A continuation of the studies reported in this paper is given in a paper by E. M. Schoenborn, G. R. Proctor and Jaime Carvajal, "The Effect of Width and of Span—Depth Ratio on the Flexural Strength of Laminated Plastics." See p. 42 of this Bulletin.

[2] Chief Physicist, Bakelite Corp., Bloomfield, N. J.

[3] 1944 Book of A.S.T.M. Standards, Part III, p. 1634.

[4] 1939 Book of A.S.T.M. Standards, Part III, p. 265.

[5] 1941 Supplement, Book of A.S.T.M. Standards. Part III, p. 322.



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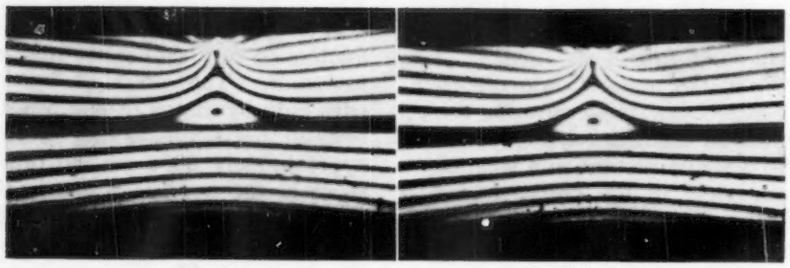

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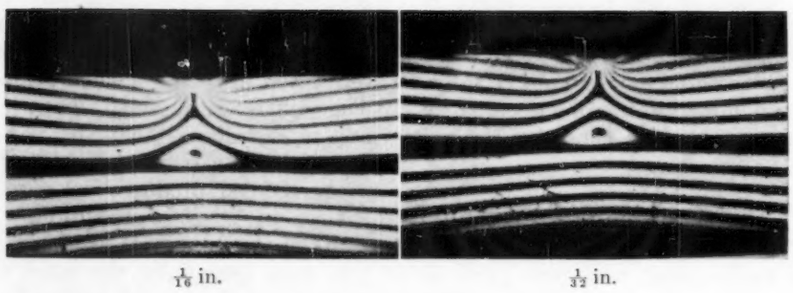
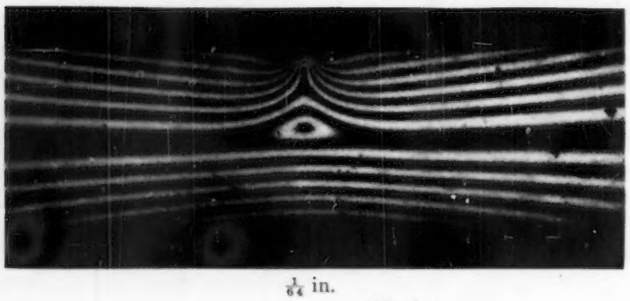


$\frac{1}{16}$ in. $\frac{1}{32}$ in.



3-Point Loading
P = 26.92 lb.
L = 4 in.
r = as shown
σ = 3034 psi.

$\frac{1}{64}$ in.

Fig. 2.

edge in order that this variable be eliminated as far as possible.

The Effect of Rate of Crosshead Motion

The effect of the rate of crosshead motion or of the rate of loading on the modulus of rupture as well as the modulus of elasticity was covered by two different laboratories. Tests were made at Rensselaer Polytechnic Institute in the Mechanical Engineering Department under the direction of Leroy W. Clark. Similar work was carried out at the Monsanto Laboratories under the direction of H. K. Nason. Both laboratories reported the results of their test to the section. The results obtained at the Rensselaer Laboratories are shown by copies of curves submitted by Clark.

A summary of the Monsanto data is given in Figs. 3, 4, and 5 showing the effect of crosshead speed on the flexural stress deflection curves for both polystyrene and cellulose acetate. Figure 5 shows the effect of crosshead speed on the maximum fiber stress obtained for both of these materials.

The results of these tests seem to indicate that the ultimate modulus of rupture or the value of the maximum fiber stress for the more flexible materials is considerably affected by the effect of speed of crosshead motion. The data also show that the speed of testing does not produce any serious effect as far as could be determined for the modulus of elasticity measurements. As a result of these laboratories' data and considerable discussion at a series of section meetings, the section recommended that the rate of loading be such that a constant rate of straining be used. This rate of straining is approximately that obtained by the old standard methods used in D 48 and D 229 which called for a crosshead motion of 0.050 in. per min. when a $\frac{1}{2}$ by $\frac{1}{2}$-in. bar was tested using a 4-in. span between supports.

Effect of Span-Depth Ratio

In all previous tests on flexural properties of plastics it was customary to use a span-depth ratio of 8 to 1. The experience of the plywood industry and the aircraft industry was such as to indicate that a larger span-depth ratio was desirable. Therefore, the section determined to investigate the subject as extensively as possible. Tests were made in three different laboratories on different types of materials.

The results obtained at the National Vulcanized Fibre Laboratories are summarized in Tables I, II, and III.

The results obtained at the Westinghouse Laboratories are shown in Figs. 6 to 8.

The results obtained at the Bakelite Laboratories are also shown in Figs. 9 to 14.

The results shown by these data are not clear cut in all respects. However, generally it is possible to draw these conclusions. The modulus of rupture obtained seems to vary some with the span-depth ratio. Generally the modulus of rupture as calculated by the conventional relationship decreases slightly as the span-depth ratio increases. The re-

TABLE I.—RESULTS OF TESTS ON LAMINATED MATERIAL TESTED AT NATIONAL VULCANIZED FIBRE CO.

Material	Thickness, in.	Direction	Span-Depth Ratio	Strength, psi., avg.	Number of Tests	Deviation, per cent, avg.
Fibre	½	Lengthwise	8	21 200	6	1.6
			16	20 900	9	1.0
		Crosswise	8	17 900	10	1.7
			16	16 500	10	2.2
	¼	Lengthwise	8	25 800	10	2.4
			16	23 700	10	2.1
		Crosswise	8	18 300	10	1.7
			16	16 700	10	1.4
	⅛	Lengthwise	8	23 200	10	1.9
			16	19 800	9	4.7
		Crosswise	8	16 000	8	2.9
			16	13 200	10	4.9
	1/16	Lengthwise	8	30 000	9	1.9
			16	26 100	10	3.0
		Crosswise	8	19 800	9	1.0
			16	18 900	10	2.0
Phenolic XXX	½	Lengthwise	8	19 500	5	4.1
			16	19 200	5	2.5
		Crosswise	8	16 600	5	4.3
			16	15 200	5	2.1
	1/16	Lengthwise	8	27 800	4	2.1
			16	26 300	5	1.3
		Crosswise	8	20 400	4	0.7
			16	20 200	5	3.0
Phenolic C	½	Lengthwise	8	19 700	10	1.5
			16	17 600	7	2.2
		Crosswise	8	19 200	7	2.3
			16	18 100	9	1.5
	¼	Lengthwise	8	21 500	8	4.3
			16	19 700	10	2.8
		Crosswise	8	20 200	9	4.0
			16	20 000	10	1.4
	⅛	Lengthwise	8	22 700	10	3.4
			16	21 400	10	2.2
		Crosswise	8	22 900	10	3.4
			16	22 200	10	3.4
	1/16	Lengthwise	8	25 200	9	3.4
			16	23 600	9	2.6
		Crosswise	8	24 000	9	2.6
			16	22 400	10	2.7

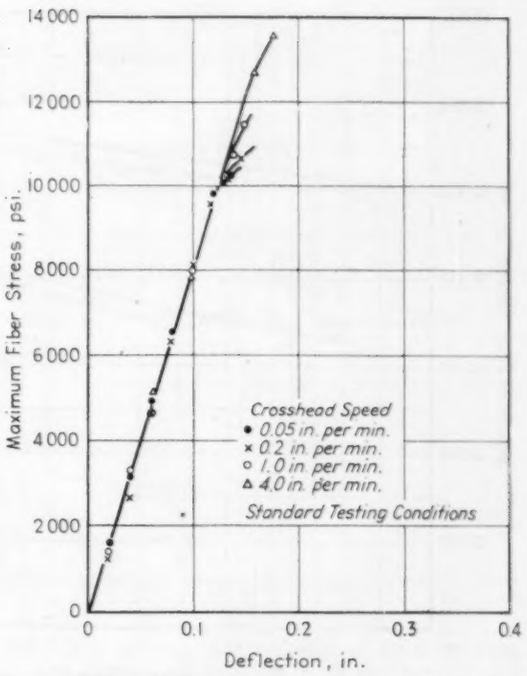


Fig. 3.—Effect of Speed on Flexural Stress Deflection Curves.

sults, however, do indicate that the rate of change of this value with flexural strength seems to be decreasing somewhat at span-depth ratios above 12. Since most of these test results were obtained by use of a constant rate of crosshead motion the rate of straining applied to the longer test specimens would be lower. This might result in somewhat lower modulus of rupture values as shown by Clark's and Nason's results.

The results of the tests at the National Vulcanized Fibre Laboratories do not indicate that greater consistency in test results would be obtained by either method.

TABLE II.—RELATION BETWEEN THE ULTIMATE STRENGTH VALUES OBTAINED BY TWO SPAN-DEPTH RATIOS.

Material	Thickness, in.	Direction	Difference Between 16 to 1 Span Depth and 8 to 1 Span Depth
Fibre	½	Lengthwise	18.8
		Crosswise	16.8
	¼	Lengthwise	8.1
		Crosswise	8.7
	⅛	Lengthwise	14.6
		Crosswise	17.5
	1/16	Lengthwise	12.8
		Crosswise	4.5
Phenolic XXX	½	Lengthwise	16.2
		Crosswise	24.1
	1/16	Lengthwise	5.5
		Crosswise	8.0
Phenolic C	½	Lengthwise	10.6
		Crosswise	5.7
	¼	Lengthwise	*8.4
		Crosswise	1.0
	⅛	Lengthwise	5.7
		Crosswise	11.8
	1/16	Lengthwise	6.3
		Crosswise	6.7

TABLE III.—RELATION BETWEEN MODULI OF ELASTICITY OBTAINED BY TWO SPAN-DEPTH RATIOS.

Material	Thickness, in.	Direction	Modulus of Elasticity: For 16 to 1 Span Depth, psi.	Modulus of Elasticity: For 8 to 1 Span Depth, psi.	Difference, per cent
Fibre	½	Lengthwise	1 330 000	1 060 000	25.4
		Crosswise	820 000	853 000	3.9
	¼	Lengthwise	1 230 000	1 030 000	19.4
		Crosswise	830 000	744 000	11.6
	⅛	Lengthwise	625 000	745 000	6.7
		Crosswise	520 000	510 000	2.0
Phenolic XXX	½	Lengthwise	1 400 000	1 300 000	7.7
		Crosswise	1 190 000	1 170 000	1.7
Phenolic C	½	Lengthwise	1 090 000	1 200 000	9.2
		Crosswise	1 060 000	1 113 000	4.9
	¼	Lengthwise	1 080 000	950 000	13.7
		Crosswise	1 030 000	990 000	4.0
	⅛	Lengthwise	1 280 000	803 000	59.5
		Crosswise	860 000	850 000	1.2

The tests on all thicknesses of the materials except the 116 in., were made on a Tinius Olsen 50,000-lb. capacity motor-driven Manual Balancing Testing Machine with deflections determined by the use of an Ames gage reading to 0.0001 in. mounted on the crosshead of the machine. Adjustments were made for the maximum load of 5000 lb., and under such an adjustment this machine can read loads to the nearest one pound. The 116-in. thick material could not be satisfactorily tested on the above-mentioned equipment and was tested on a Steel City Testing Machine of the Hydrualic Type of 3500-lb. capacity, adjusted for a maximum load of 350 lb. With this adjustment the machine is capable of reading ½-lb. loads.

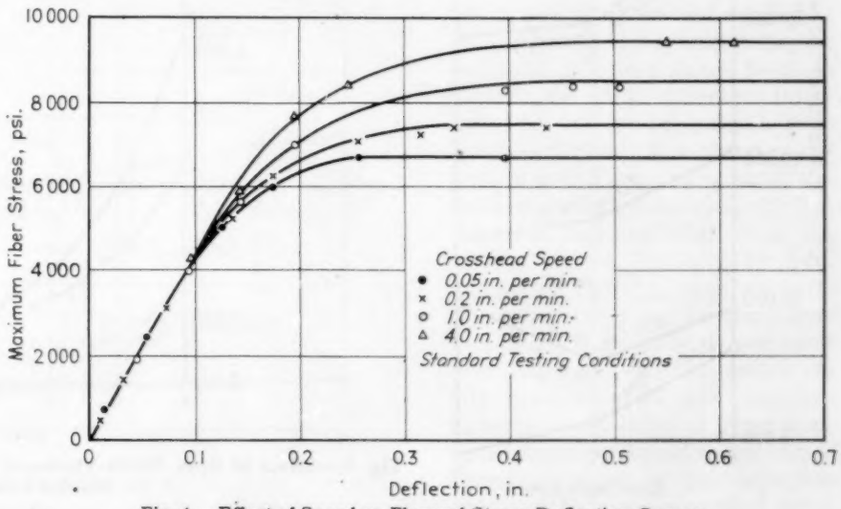


Fig. 4.—Effect of Speed on Flexural Stress Deflection Curves.

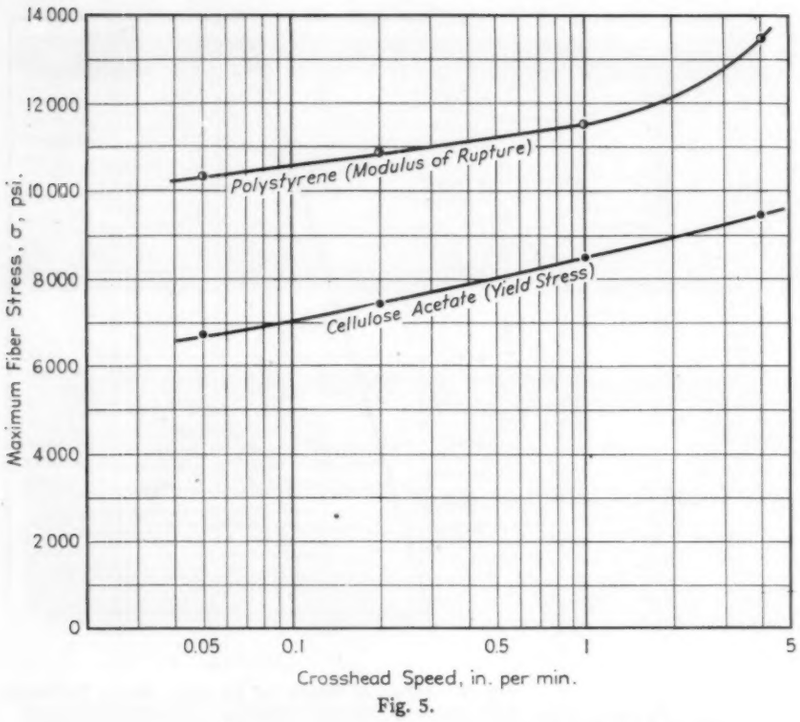


Fig. 5.

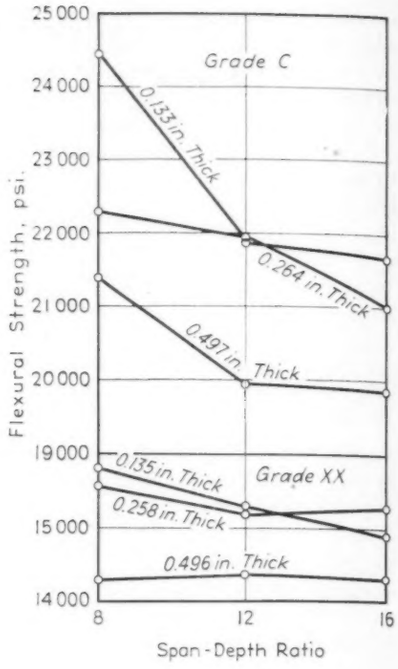


Fig. 7.

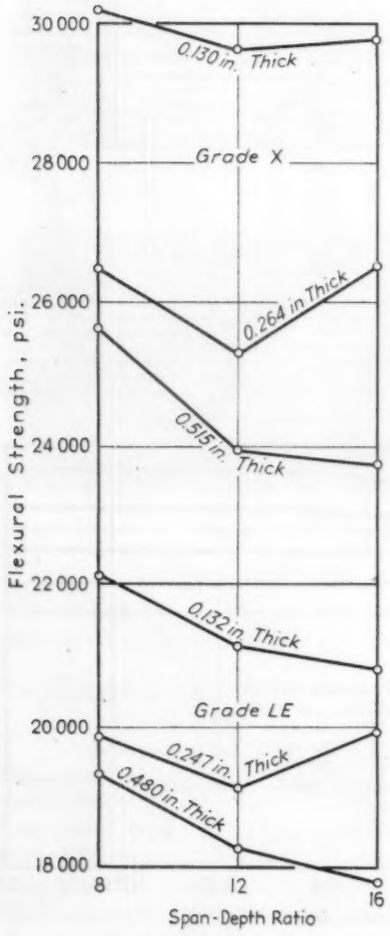


Fig. 6.

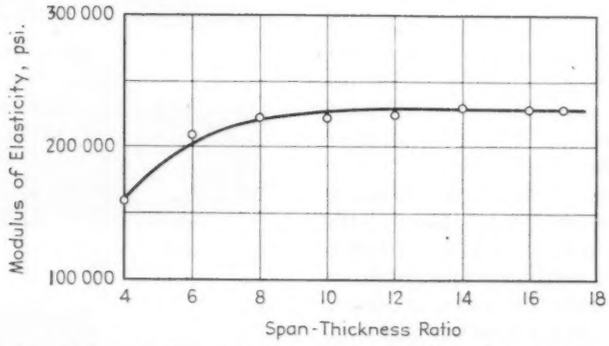


Fig. 8.—Effect of Span Width-Thickness Ratio on Apparent Modulus of Elasticity by Flexural Test of Injection Molded Cellulose Acetate. Test Specimens ¼ by ½ by 5-in.

$$\text{Modulus of Elasticity } M = \frac{PL^3}{4bd^3l}$$

where: L = span width, l = deflection, b = width.
P = load producing, d = thickness, and

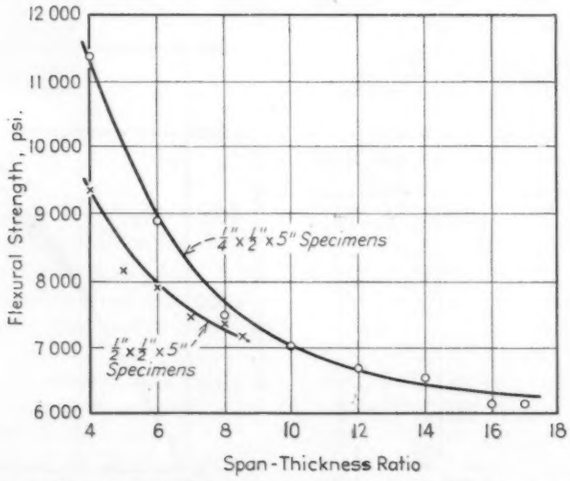


Fig. 9.—Effect of Span Width-Thickness Ratio on Flexural Strength of Injection Molded Cellulose Acetate.

$$\text{Flexural Strength} = \frac{3PL}{2bd^2}$$

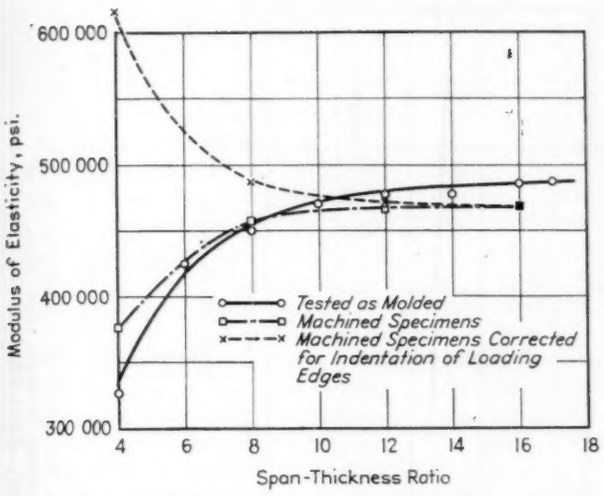


Fig. 10.—Effect of Span Width-Thickness Ratio on Apparent Modulus of Elasticity by Flexural Test of Injection Molded Styron. Test Specimens ¼ by ½ by 5-in.

$$\text{Modulus of Elasticity } M = \frac{PL^3}{4bd^3l}$$

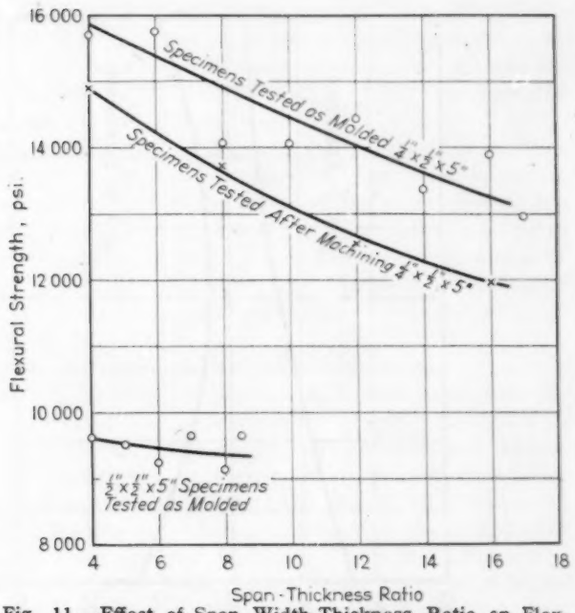


Fig. 11.—Effect of Span Width-Thickness Ratio on Flexural Strength of Injection Molded Styron.

$$\text{Flexural Strength} = \frac{3PL}{2bd^2}$$

Theory in the field of mechanical engineering indicates that the 8 to 1 span-depth ratio throws this testing into what is usually called the short beam test in which case there seems to be considerable possibility of introducing error due to shear stresses during the testing procedure. Generally, mechanical engineers favor the longer beam or longer span-depth ratio for that reason.

The results of the tests in these three laboratories also indicate that generally the modulus of elasticity as calculated by the conventional deflection equation increases somewhat for the longer span-depth ratios. The reason for this may be the result of two things: One, the fact that the conventional deflection equation is based on the assumption that the effect of shear stresses is negligible, and, second, that the popular technique of measuring deflections may introduce an error because of the indentation of loading edges.

When the simple beam method of test is used with the load applied at the midspan line a correction in the measured deflection should be made because the shear deflection introduced by the low span-depth ratio is not negligible. The observed deflection is too large by a factor depending on the geometry of the test specimen and the location of the loading edges. For a ½ by ½-in. bar tested on 4-in. span supports this correction factor for the deflection is approximately 5 per cent. For a ½ by ½-in. bar tested on 8-in. span supports this correction factor is of the order of 1 per cent. This correction should be applied to observed values of the deflection produced by a given applied increment of load. The result of such a

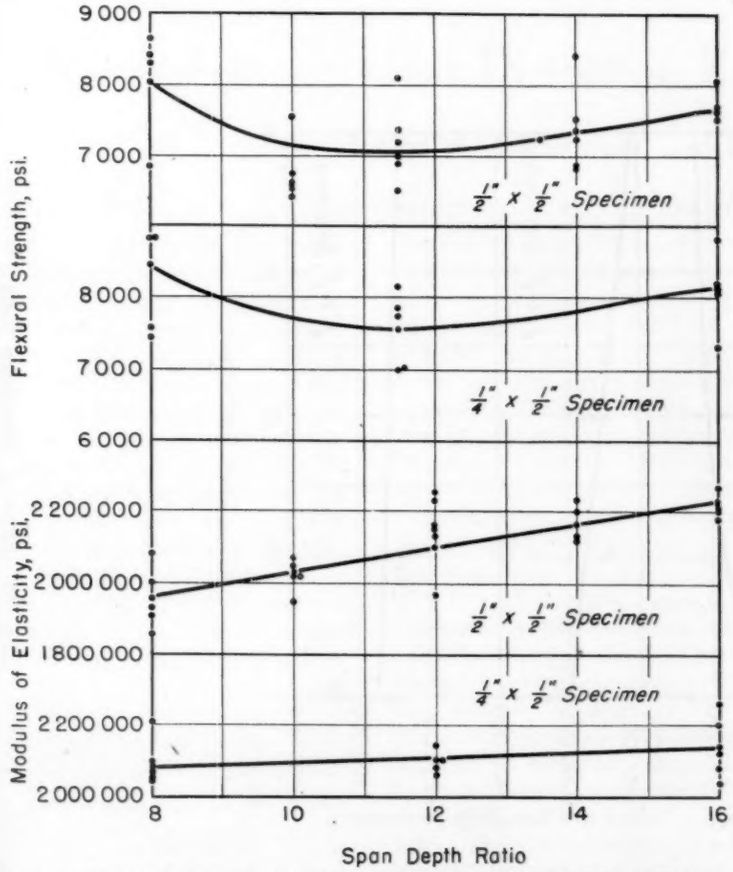


Fig. 12.—Effect of Span-Depth Ratio on Flexural Strength and Modulus of Elasticity of BM-021.

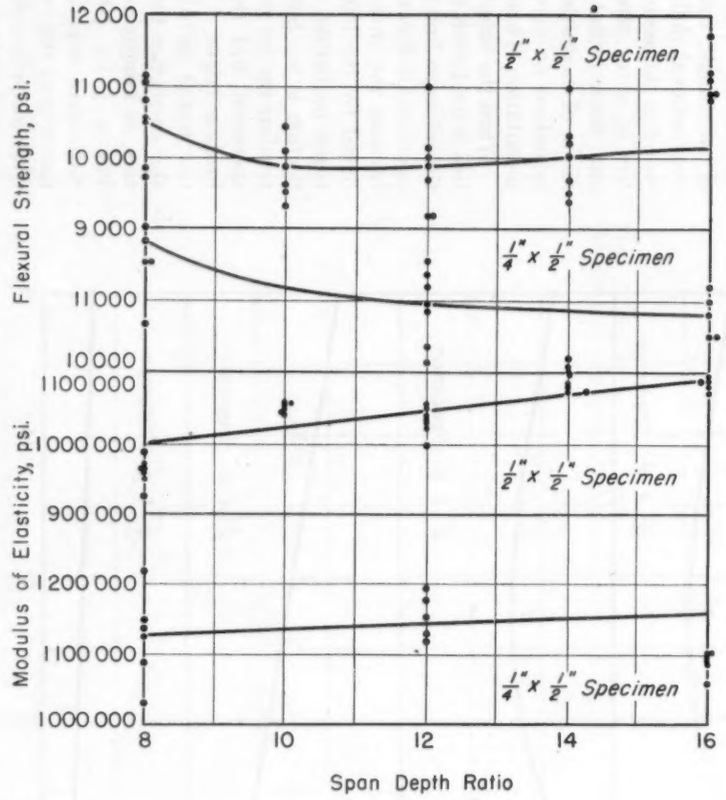


Fig. 13.—Effect of Span-Depth Ratio on Flexural Strength and Modulus of Elasticity of BM-261.

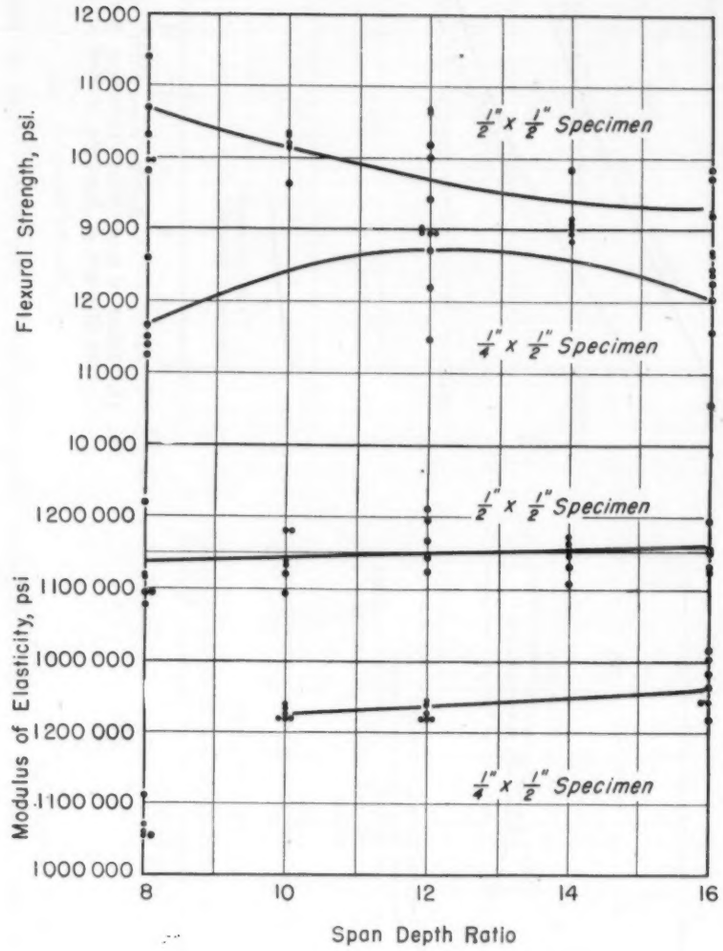


Fig. 14.—Effect of Span-Depth Ratio on Flexural Strength and Modulus of Elasticity of BM-3510.

correction would be a higher modulus of elasticity than was actually calculated using always the simplified beam formula.

Another error frequently found in measurements of modulus of elasticity is the error in the apparent deflection caused by the indentation of the loading edges. For soft materials, such as plastics, the loading edges make an indentation in the specimen. If the deflection of the test bar is measured, as it frequently is, with a dial gage micrometer the measurement made is usually the relative motion of the two sets of loading edges. Sometimes the deflection of the midpoint of the bar relative to the supporting edges is used. Any indentation of the supporting or loading edges would then tend to give an apparent deflection reading for the test specimen which is too high by the amount of this indentation. For example, it was found in the Bakelite Laboratories that for a phenolic material tested with a $\frac{1}{2}$ by $\frac{1}{2}$-in. bar on a 4-in. span support this indentation was usually between 7 and 15 per cent of the deflection used in calculating the modulus of elasticity. In some cases indentations as high as 25 per cent of the deflection were observed. Since a longer span results in both reduced loads and larger deflections for a given material and since the amount of indentation is largely a function of the load applied to the indenting edge, such an increase in the span-depth ratio from 8 to 16 will reduce this error to less than 1 per cent. Figure 10 of the Bakelite data indicates that if the modulus of elasticity is calculated from corrected and uncorrected deflections due to indentation of the loading edges, with a span-depth ratio of 8 the error introduced in modulus calculations is approximately 10 per cent while with a ratio of 16 the error is negligible. Thus, the use of the larger ratio obviates the necessity for determining the amount of indentation for each test and relieves the laboratory from considerable extra work.

Because of the above information obtained from theory and experiment the members of the section are suggesting that a span-depth ratio of 16 be used in making modulus of rupture and modulus of elasticity measurements.

Acknowledgments:

The author wishes to express appreciation to Messrs. Anderson of Westinghouse Electric and Manufacturing Co., Clark of Rensselaer Polytechnic Institute, Nason of Monsanto Chemical Co., and Mains of National Vulcanized Fibre Co. for making available the information and data supplied from their test results. Originals of the curve sheets were supplied by the respective laboratories making the tests.

An Automatic Heat Distortion Recorder for Plastics[1]

By George A. Heirholzer[2] and R. F. Boyer[2]

HEAT distortion tests to characterize certain aspects of the high-temperature behavior of polymers have been widely used in the plastics industry. Usually a sample of specified dimensions is loaded in a prescribed manner and heated at a fixed rate until the deformation reaches a stated value. The temperature corresponding to this deformation is known as the heat distortion temperature. A.S.T.M. Tentative Method of Test for Heat Distortion Temperature of Plastics (D 648–44 T)[3] gives complete details on apparatus and procedure for carrying out such a test. This method offers the advantages of speed and simplicity but has the disadvantage of giving only a single point on the deformation *versus* temperature curve. So long as a series of related polymers are being compared, this limitation may not be serious. However, with the advent of new plastic types, and combinations of plastics with inorganic fillers, the character of the deformation-temperature curve may be sufficiently unique to require a complete determination.

This problem has already been pointed out by Pechukas, Strain, and Dial[4] who found that some of the allyl polymers may show more deformation at low temperature than thermoplastics and yet be far superior at elevated temperatures. In such cases a comparison of heat distortion temperatures is entirely misleading. It is possible, of course, to obtain with the equipment specified in the A.S.T.M. methods a complete deformation-temperature curve by making point by point observations. In this connection a recent article by Sauer, Schwertz, and Worf[5] presents more than forty deformation-temperature curves on most of the commercially available plastic materials. A modified A.S.T.M. apparatus designed to correct for thermal expansion of the specimen was employed. These results emphasize quite well the value of knowing the complete deformation characteristics of each material. However, obtaining such data quickly becomes tedious when a large number of samples are to be investigated. It seemed appropriate, therefore, to develop an automatic apparatus which would plot the deformation-temperature

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia 2, Pa.

[1] This paper was presented at a meeting of Subcommittee III on Thermal Properties of Committee D-20 on Plastics held on March 16, 1945, at Atlantic City, N. J.

[2] Physical Research Lab., Plastics Development Div., The Dow Chemical Co., Midland, Mich.

[3] 1944 Book of A.S.T.M. Standards, Part III, p. 1627.

[4] A. Pechukas, F. Strain, and W. R. Dial, *Modern Plastics*, Vol. 20, June, 1943, p. 101.

[5] J. A. Sauer, F. A. Schwertz, and D. L. Worf, *Modern Plastics*, Vol. 22, March, 1945, p. 153.

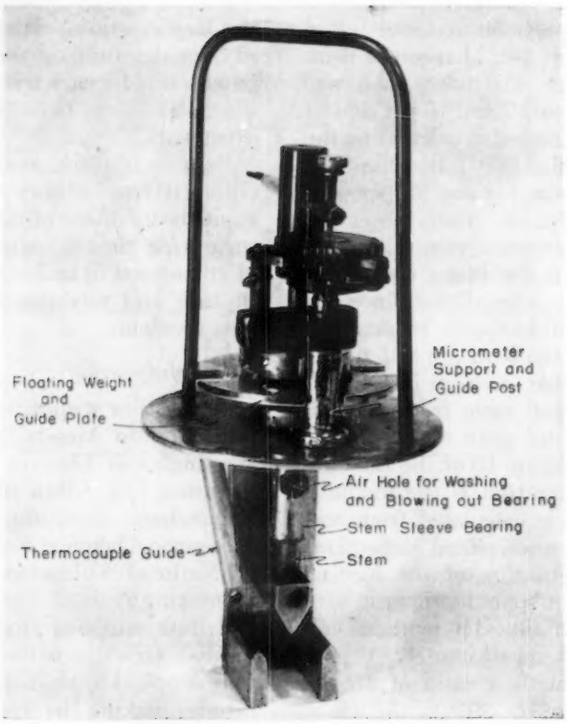


Fig. 1.—Specimen Holder, with Ratchet Wheel Attached to Head of Micrometer. The Guide Plate and Guide Post Prevent the Floating Weight from Rotating About Its Own Axis.

behavior in approximately the same time now required for a heat-distortion measurement. This article describes such equipment and illustrates some typical results.

Description of Apparatus

The Laboratories of The Dow Chemical Co. have used for some years a heat-distortion unit designed by R. D. Lowry which is in effect a miniature of the present apparatus specified in Method D 648. The specimen holder is shown in Fig. 1. The main point of departure is one of specimen size. A sample $1\frac{3}{4}$ by $\frac{1}{2}$ by 0.1 in. is supported flatwise on 1-in. centers with a floating load of 258 g. on the center. A deformation of 5 mils with this arrangement corresponds quite closely to the heat-distortion point obtained with regular A.S.T.M. equipment. The advantages of this system are the small amount of material required for a test, the more rapid heating of the sample, and the smaller contribution of thermal expansion. Three or more such heat-distortion bars can be cut from a 7-g. compression molding which measures $1\frac{3}{4}$ by $2\frac{1}{2}$ by 0.1 in. thick. Tensile strength and impact bars are also cut from the same molding. It is not our purpose here to advocate any change in existing methods or to claim any marked superiority for the system just described.

The point is that heat-distortion units of the type shown in Fig. 1 were available and formed the nucleus of the automatic unit which will now be described. On the micrometer head of the unit shown in Fig. 1 was placed a ratchet wheel having fifty teeth, each tooth therefore corresponding to 0.0005-in. displacement of the micrometer. The ratchet could be advanced one tooth at a time by a lever arm driven from an eccentric shaft which made one revolution each time electrical contact was established between the floating weight and the micrometer head. Figure 2 shows the essential features of this arrangement.

The mode of operation is as follows. When electric contact is established at the micrometer head, the terminals *A*, *B* on the electronic relay are shorted. This causes the electronic relay to close the double pole switch, one side of which completes the circuit to the cam motor. The eccentric drive advances the ratchet, thereby breaking contact at the micrometer head. Normally the cam motor would stop as soon as this micrometer head contact is opened. However, the other side of the double pole switch closes a circuit through the microswitch resting on the cam and thus shorts the terminals *A*, *B* until the cam has made one complete revolution. At the end of the revolution, the roller on the microswitch drops into the cut-out section of the cam, thus opening the circuit which was

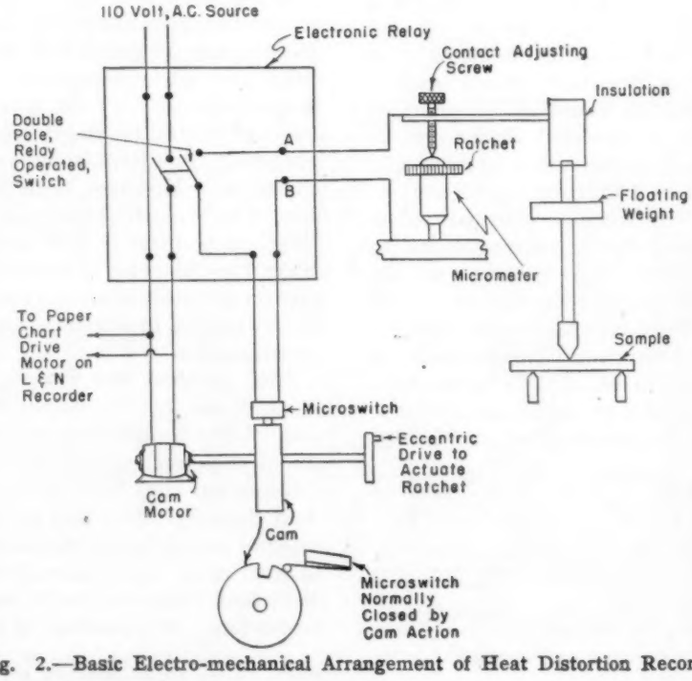


Fig. 2.—Basic Electro-mechanical Arrangement of Heat Distortion Recorder.

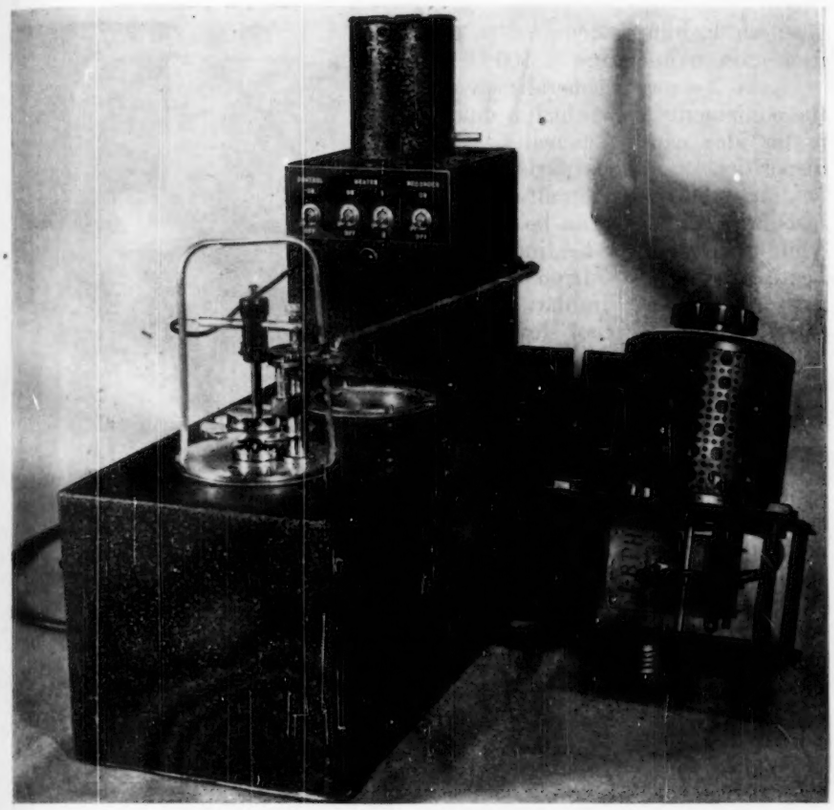


Fig. 3.—General View of Automatic Heat Distortion Apparatus. The Recorder Is Located at the Right Side of the Variac.

shorting the terminals A, B. Since the circuit going to the micrometer head is also open, nothing more will happen. Of course the coasting of the cam motor brings the microswitch back to its closed position, but by this time the double pole switch has opened. In this manner the cam shaft makes exactly one revolution per electrical contact at the micrometer head, and the ratchet on the micrometer head is advanced by exactly one tooth. It will be noted that when the cam shaft motor is operating, electrical energy is also provided for the chart paper drive motor on the recorder. The reason for this will be apparent in the next paragraph.

What happens in practice is this. A sample is placed in the unit and the micrometer is set to zero. The contact screw is adjusted to make contact with the micrometer head. This actuates the electric motor which causes the cam shaft to make one revolution. The ratchet is advanced one tooth, thereby leaving a 0.0005-in. gap between the contact arm and the head of the micrometer. This electro-mechanical system now rests until the sample, which is being heated, has deformed 0.0005 in. Electrical contact is established once more, only to be broken when the ratchet advances by one more tooth. These events are recorded on a Leeds & Northrup recorder in a simple fashion. A thermocouple resting on the specimen tells, through the recorder, the temperature of the specimen. Thus the temperature axis of the recorder performs its normal function. However, the chart paper drive motor on the recorder operates, not continuously, but only while the cam shaft is making its revolution. The recorder chart paper advances roughly $\frac{1}{4}$ in. each time electrical contact is made at the micrometer head—and hence each time the specimen has deformed by 0.0005 in. This corresponds to a 500-fold amplification of the sample distortion without the use of mechanical or optical levers. The resulting heat-distortion curve therefore consists of a series of steps, as shown in Fig. 6. The tenth step, corresponding to a total sample deflection of 0.005 in. is considered the heat-distortion

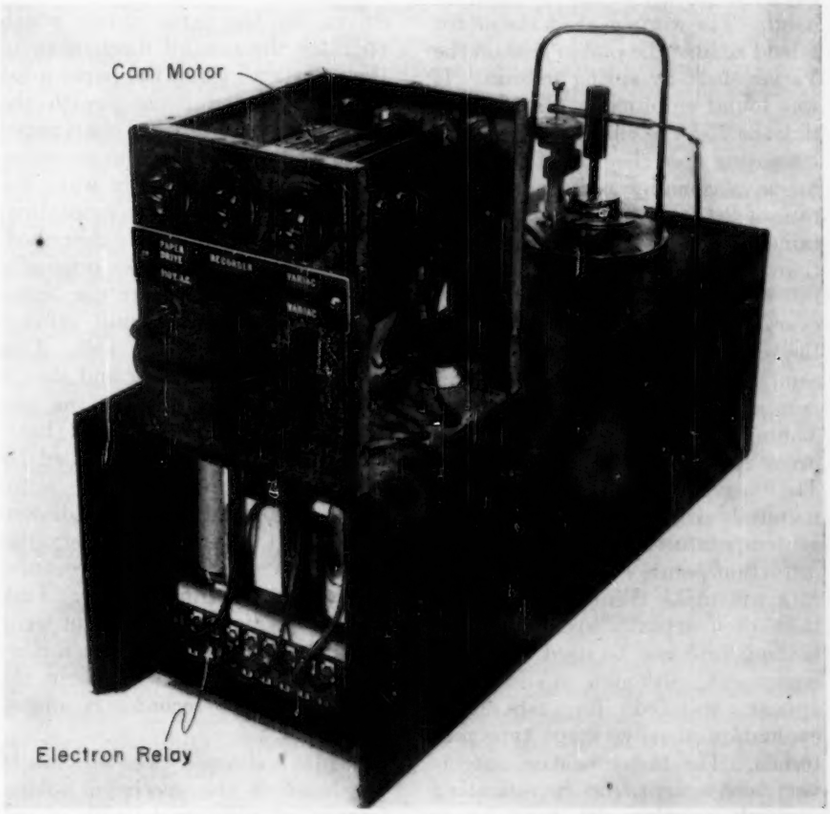


Fig. 4.—Rear View of Apparatus, Showing Location of the Electron Relay, the Cam Motor, and the Electrical Outlets.

temperature, while the entire deformation-temperature curve is permanently available for noting any peculiarities about sample behavior.

The cam motor operates at a speed of 20 rpm. and hence approximately 3 sec. are required to complete one of the cycles corresponding to 0.00005 in. deflection. If the sample is deforming at a rate faster than 0.0005 in. per 3 sec., the mechanism operates continuously. The recorded curve becomes a continuous line which does not give a true indication of the actual sample deformation. A faster cam motor can be employed although the present speed of 20 rpm. appears adequate for most work.

Auxiliary equipment is, of course, required. A heating chamber which will raise the temperature of the specimen at a uniform rate consists of a metal can about which is wound a 600-w. Chromalox heating coil. This coil is supplied with energy from a Variac driven by a 1-rph. clock motor through a worm gear. This clock motor is so mounted that it can be moved out of operating position to allow the Variac to be adjusted quickly to any position by hand. The worm gear on the motor is held against the pinion gear on the Variac shaft by spring tension. It was found empirically that by setting the 750 VA Variac at 32 v. and increasing it at the rate of 10 v. per hr. a reasonably uniform heating rate of 2 C. per min. would be obtained. This is considerably faster than the recommended A.S.T.M. rate of not over ½ C. per min. However, with the thin specimens used the temperature at the center of the sample will never lag the bath temperature by more than 0.1 C. There is thus a definite time-saving involved by this faster heating rate. The only disadvantage occurs with materials which creep considerably at temperatures below their heat-distortion point. This fast heating rate will make them appear better than they actually are. A slower heating rate can be used with this equipment, although it does not appear justified for laboratory evaluation of polystyrene type materials. The faster heating rate is very convenient for investigating research samples with heat-distortion temperatures in excess of 100 C. Even so 40 min. is required to go from room temperature to 100 C.

Figure 3 shows a general view of the equipment, from which a much better idea can be gained of the disposition of various parts. Two heating wells are used in alternating fashion so that one can be cooling while the other is heating. The heating wells are surrounded by Santocel for heat insulation, and they consequently cool slowly. It was found that a stream of cool air could be played into the heating well to aid cooling. The specimen holder is cooled after each use by placing it in the small air-cooled cylindrical chamber on top of the control box. Through alternate use of the two heating chambers and air cooling of the specimen holder between runs, the unit can be operated without interruption, and hence at maximum efficiency. Figure 4 shows a rear view of the equipment with the cover removed from the control box. The location of the cam motor, the electronic relay, and the electrical outlets are the main points of interest.

The paper chart on an Leeds & Northrup recorder is normally driven by the same motor which operates the control mechanism of the recorder. Since the paper must be driven intermittently with the present system, a special chart paper drive is installed on the recorder. This motor operates only when the camshaft is making its revolution, in the manner previously described. In our case the recorder originally had an automatic calibrating device to standardize the null circuit against the standard cell. This operated once each hour and always involved some motion of the pen arm. Because the recorded heat-distortion curve was disturbed by this extraneous motion, the automatic calibrating unit was disconnected. It is, of course, very important to standardize the recorder by hand at least once a day. Failure to do this has resulted in some inordinately high heat-distortion temperature, especially when the dry cell in the recorder is almost exhausted.

Figure 5 shows a close-up view of the head of the specimen holder, from which additional details of construction can be gained. Any further description would involve detailed parts drawings which do not appear to be in order. Our main purpose in presenting this material has been to emphasize the value of the complete deformation-temperature curve and to illustrate the operating principles of one type of apparatus which will yield such curves. A recording plastometer developed by Biondi of the Bell Laboratories may be of interest when considering other types of designs.[6] Incidentally, our equipment has been used, with minor modifications, to record deformation *versus* time curves at constant temperature. In this case the pen arm of the recorder is driven by a clock motor at a constant rate such that the pen traverses the temperature scale from 0 to 200 C. in some fixed time, for example 24 hr. The chart paper moves each time the specimen has deformed by 0.0005 in. The galvanometer control on the recorder is disengaged for such work. It is also possible to measure thermal expansion by employing a thicker plastic sample which rests on a rigid base plate, such as glass or metal. Minor corrections for differential expansion of the instrument parts would be needed in such a case, and the ratchet would have to be reversed.

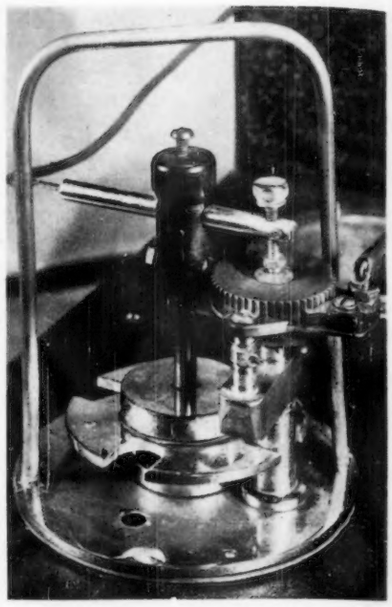


Fig. 5.—Detail View of Head of Specimen Holder.

[6] F. J. Biondi, *Bell Laboratory Record*, Vol. XXI, September, 1942, p. 18.

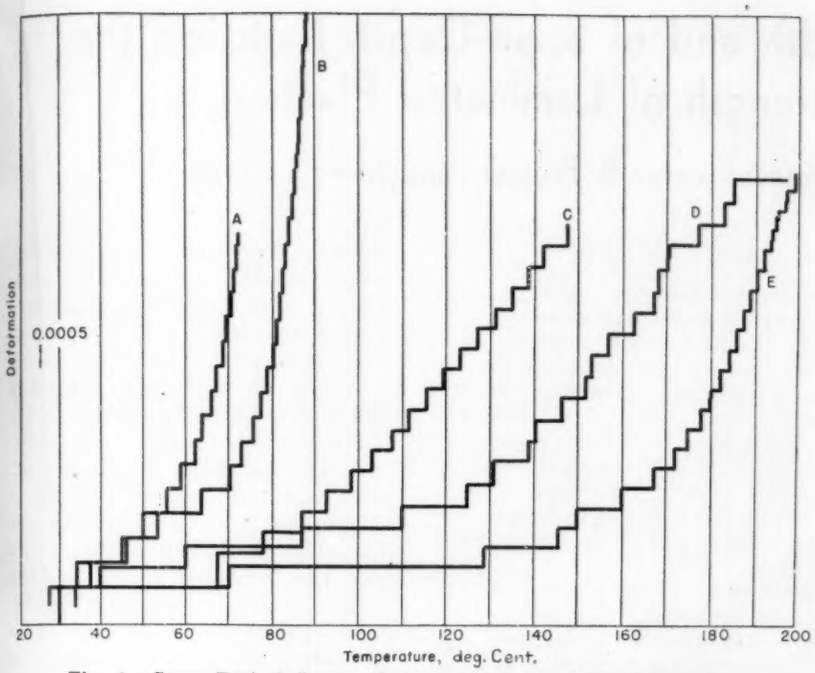


Fig. 6.—Some Typical Curves, Redrawn from the Original Records.

Curve *A*, Styraloy 22; curve *B*, Experimental Plastic Q-127; curve *C*, Silicone-Fibreglas laminate; curve *D*, Bakelite BM-3510; curve *E*, Bakelite BM-120.

Some Typical Results

The ease of operation of these heat-distortion units allows them to be used for control purposes on standard plastic materials. However, their main advantage lies in the routine evaluation of new laboratory materials. Figure 6 shows some typical curves which have been obtained. These five curves portray in a general way the wide variety of results that can be expected. The standard thermoplastic materials usually give the same type of exponential curve, while the newer types of higher heat-distortion thermoplastics reveal minor but quite interesting variations. The thermosets exhibit many interesting features, such as a "thermoplastic" behavior over a narrow temperature interval, without additional deformation even at much higher temperatures. It is planned that other curves illustrating more variations than shown in Fig. 6 can be presented elsewhere.

Some Notes on Operation

A number of heat-distortion units of the general type described here have been used in our Plastic Laboratories for several years. The experience gained in operating these units may be of value to anyone contemplating the construction of such equipment. The first general principle is that an automatic instrument of this type should not be considered infallible. It frequently makes mistakes so that a constant scrutiny of its performance is advisable. Each day the vertical stem of the sample holder, through which the floating weight slides, should be cleaned with carbon tetrachloride and blown out with dry air. The head of the micrometer and the contact point should be polished with fine emery paper to ensure good electrical connections. A standard specimen should be checked for heat distortion at least once a day. It is usually well to check the appearance of any new type of material at the completion of the run. We have noted some samples which tend to delaminate under heat and thereby to expand sufficiently to offset much of the sample deformation. This causes an erroneously high heat-distortion temperature. The heating rate should be checked every few months since the heaters may change slowly with time or develop poor contacts. Eventually, of course, some of the moving parts will wear. The unit shown in Fig. 3 needed some replacement parts after it had made 2000 records.

The appearance of the heat-distortion curve itself is usually a good criterion of the performance of the instrument. The steps in the curve should be regular and free from extraneous wiggles and movements. An excellent "standard sample" suggested to us by P. C. Woodland of our laboratory is a bimetallic strip placed in the specimen holder so that it will bow downward on heating. The resulting curve should resemble stair steps of perfectly uniform rise.

One other operating detail might be mentioned. The curves are recorded, not on strip chart paper but on individual sheets of graph paper especially prepared for this purpose. This graph paper, which facilitates the making of blueprint copies, is fastened to the strip chart paper on the recorder with pressure-sensitive gummed paper. Incidentally, it has been found advantageous to install limiting devices which will sound an alarm when the deformation has reached a given amount, or when the temperature has reached 200 C. It may even be advantageous to have a current cut-off which will turn off the heater when the temperature exceeds 200 C.

Lists of Parts

Following is a list of some of the major items used in the construction of the heat-distortion units. The case was constructed from 20-gage galvanized iron and protected with a crackle finish paint.[7]

1—Leeds & Northrup Micromax Recorder with a 0 to 200 C. temperature scale, using an iron-constantan thermocouple.

1—Holtzer-Cabot type RWC-2505 60-rpm. motor to drive the chart paper on the recorder.

1—Type 200 C General Radio Variac.

1—Syncron, 1-rph., type 600 motor to drive Variac, using a four-thread wormgear and a 50-tooth spur gear.

1—United Cinephone Electron Relay.

1—Minneapolis-Honeywell Electric Janitor for the cam motor. The switching mechanism and the two lower gears are removed, while a shaft extension is made on the third gear to give 20 rpm.

2—5/16-in. O.D. Chromalox 600-w. tubular heaters wound around the lower half of each heating well.

It is difficult to make a precise estimate of the cost of these units since it depends to a large extent on the care used in constructing and assembling the parts. It is believed that $1000 will cover the complete unit, including the recorder.

[7] Black surah baking finish, John L. Armitage and Co., Newark, N. J.

The Effect of Width and of Span-Depth Ratio on the Flexural Strength of Laminated Plastics

By E. M. Schoenborn,[1] George R. Proctor,[2] and Jaime Carvajal[2]

SYNOPSIS

The inadequacy of current testing procedures for the determination of the flexural characteristics of rigid plastic materials has promoted a comprehensive study of the test method. A program to evaluate the effect of different test variables on the modulus of rupture and modulus of elasticity has been undertaken in an effort to develop better testing techniques and to gain a more intimate knowledge of their significance.

This report describes briefly the results obtained to date from over five hundred flexural tests carried out in these laboratories. Laminated phenolic sheet, grades X and C, and vulcanized bone fibre sheet were tested at span-depth ratios of 8, 12, 16, and 24 to 1 and in widths varying from ¼ in. to 1 in. Specimens were cut both lengthwise and crosswise from ¼ and ½-in. sheet stock.

Nearly all tests were remarkably consistent, calculated values of flexural strength and modulus exhibiting average deviations within ± 3 per cent of the mean of 5 to 10 determinations. In general, calculated maximum fiber stress at rupture was found to decrease, and the modulus to increase, with increasing span-depth ratio. The effect of width of specimen appeared anomalous, particularly for the phenolic materials, since samples cut lengthwise showed increasing strength, while those cut crosswise gave decreasing values, as the sample width increased. Both the flexural strength and modulus calculated for the fiber were independent of width over the range covered. Only two thicknesses of sheet were included in this investigation so that no general statements regarding the effect of specimen depth can be made at this time.

Several correlations of the observed data were made which show that the formulas currently being used to calculate ultimate flexural stress and modulus of elasticity are not rigorous for the materials studied. A plot of breaking load P *versus* specimen dimensions, L/bd^2, however, indicates P to be a power function of the latter group of variables, the exact function being dependent upon the nature and direction of the material. A more fundamental approach to the behavior of inelastic materials in flexure is, therefore, indicated.

MEANS for determining the physical properties of plastics by standardized methods and procedures have become of increasing importance, particularly where applications of a structural character are concerned. Furthermore, a knowledge of the behavior of these materials, as interpreted through sound testing methods, is a prime consideration in engineering design. Among the more important mechanical properties which must be evaluated before any significant comparison of rigid materials can be made is that of flexural strength.

Because of the uncertainties existing in an interpretation of the flexural test method as a consequence of the large number of variables involved and because of the anomalous results obtained by methods currently in use, a broad program directed toward a careful evaluation of the test method has been undertaken.

A series of round-robin tests was carried out some time ago by Section F, Subcommittee I of A.S.T.M. Committee D-20 on Plastics and the results were summarized by W. A. Zinzow.[3] The need for modification of the then existing flexural test method was apparent and specific changes were recommended. At the same time, a continuation of the study covering an even wider range of test variables and materials appeared desirable so that the present investigation was initiated.

A preliminary report describing the general philosophy of approach was presented to A.S.T.M. Committees D-9 on Electrical Insulating Materials and D-20 on Plastics at their meetings held in Atlantic City, October 24 to 27, 1944. Since that time over 500 tests have been made on two types of phenolic-laminated material and on vulcanized fibre, and it is the purpose of this report to present briefly the results obtained and the implications of these results with regard to future work.

EXPERIMENTAL

Testing Equipment:

All flexural tests were carried out in a specially constructed air-conditioned room maintained at 77 F. and 50 per cent relative humidity. Samples of phenolic previously cut to size were conditioned in this environment for a period of at least six weeks prior to testing. The fibre was conditioned in a circulating air oven at 50 C., stored in desiccators and tested immediately upon removal therefrom in the manner prescribed in A.S.T.M. Tentative Methods of Conditioning and Classifying for Conditioning Plastics and Electrical Insulating Materials for Testing (D 618–44 T).[4]

A Baldwin Southwark Tate-Emery Universal Testing Machine of 60,000-lb. capacity was employed for all tests. This unit is equipped with an automatic stress-strain recorder which, by means of a special adaptation of a set of extensometers for measuring relative crosshead motion, permits the recording of a load-deflection diagram for each test. The recorder eliminates the necessity for tedious dial gage readings and permits a single operator

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia 2, Pa.

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[3] See p. 31 of this BULLETIN.

[4] 1944 Book of A.S.T.M. Standards, Part III, p. 1385.

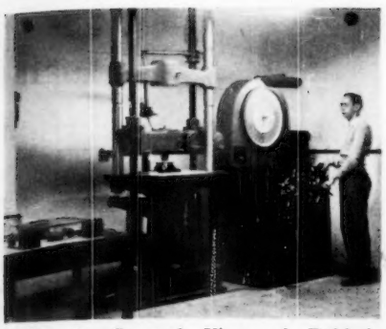


Fig. 1.—General View of Baldwin Southwark 60,000-lb. Testing Machine in Air-Conditioned Laboratory.

to perform the necessary operations easily and quickly. An attachment especially developed to utilize an extensometer for measuring relative crosshead motion is described later. A standard set of Sonntag flexure tools having supports and loading nose with $\frac{1}{8}$-in. radii, standard dial indicators, and other necessary fixtures are available.

A general view of the testing machine is shown in Fig. 1; the present arrangement for the flexural tests is shown in Figs. 2 and 3.

Extensometer Attachment.—In order to obtain an accurate load-deflection diagram with the recorder, a high magnification extensometer is being used to measure relative crosshead motion. For hard materials, indentation at the supports and nose is found to be negligible so that the motion of the platen relative to the fixed crosshead serves to give a good indication of beam deflection. For softer materials, a modification of this scheme will have to be devised and it is hoped a means can be found for measuring sample deflections directly from the specimen and of recording them with the stress-strain instrument.

The extensometer attachment (Fig. 4) consists essentially of two short brass rods, one sliding within the other, to which the knife-edges of the extensometer can be securely fixed. The lower rod is screwed into a heavy base which rests on the fixed crosshead. The upper brass rod is engaged through a ball and socket joint with a long thin steel rod which slides through a hollow brass fixture containing a set-screw. This fixture is machined to fit into the steel wedge used to suspend the upper set of a pair of Templin tension grips. In this way the device is kept in alignment and adjustment of the fixed crosshead is readily made without removing the extensometer. A high magnification extensometer with a range of 0.20 in. is currently being used at a magnification ratio of 100. Thus, a deflection of 0.01 in. is recorded on the strip chart through a distance of 1 in.

Materials:

While it is planned to continue investigation of the flexural strengths of numerous other plastics, the tests described herein were confined to grades X and C phenolic-laminated sheet material and to Bone Grade vulcanized fibre. A large quantity of these samples cut both crosswise and lengthwise of the sheet was generously supplied by Continental-Diamond Fibre Co. and National Vulcanized Fibre Co., Newark, Del. Other samples not yet tested include phenolic-laminate and Pregwood supplied by Synthane Corp. and Formica Insulation Co., respectively.

Test Variables:

Data were obtained on the above materials at span-depth ratios of 8, 12, 16, and 24 to 1 using samples of $\frac{1}{4}$ and $\frac{1}{2}$-in. depths and $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1-in. widths. The testing speed utilized was determined for each sample size from the formula as recommended in A.S.T.M. Tentative Method of Flexural Test of Plastics (D 790 – 44 T)[5]:

$$N = 0.01L^2/6d \quad \ldots\ldots\ldots (1)$$

where:

d = depth of beam as tested in inches,
L = distance between points of supports (span) in inches, and
N = rate of crosshead motion in inches per minute.

[5] 1944 Book of A.S.T.M. Standards, Part III, p. 1634.

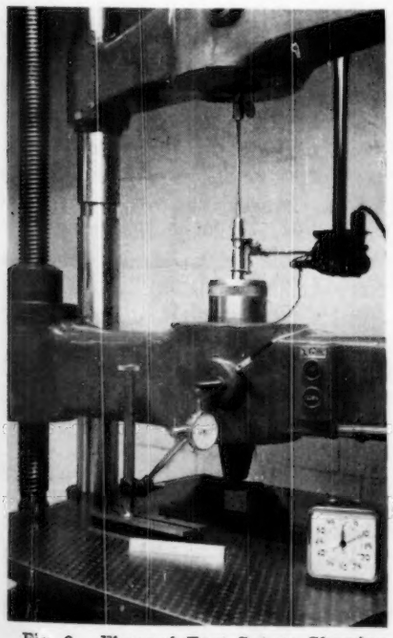


Fig. 2.—Flexural Test Set-up Showing Extensometer Arranged to Record Relative Crosshead Motion.

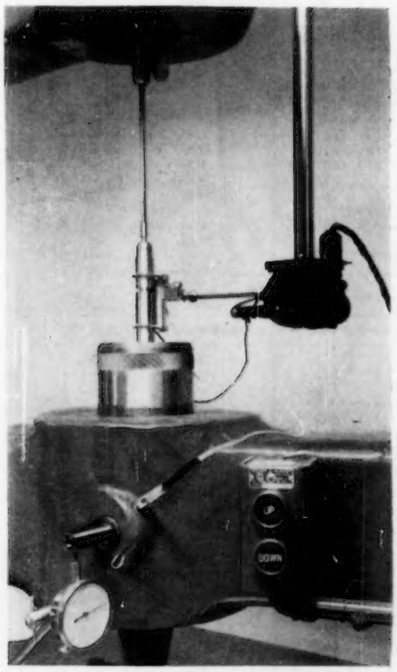


Fig. 3.—Extensometer Attachment in Position.

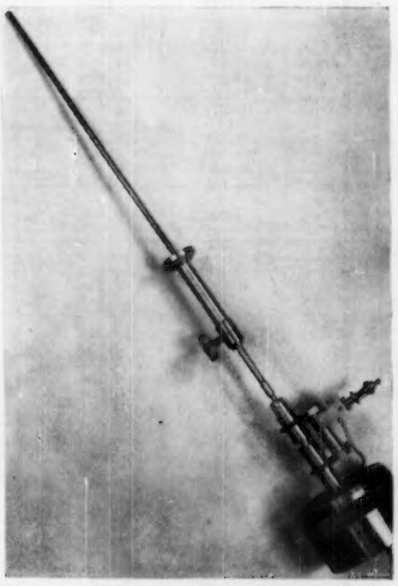


Fig. 4.—Extensometer Attachment for Flexural Test.

TABLE I.—OBSERVED DATA AND CALCULATED RESULTS.

Number of Samples	Depth, d, in.	Width, b, in.	Span, L, in.	Breaking Load, P, lb.	Flexural Strength, S, psi.	Average Deviation, per cent	Span-Depth Ratio, L/d	Modulus of Elasticity E_B, psi.	Average Deviation, per cent	
Grade X Phenolic Laminate										
5..	0.254	0.253	2	138	25 500	±3.8	8	1 380 000	±2.6	
5..	0.257	0.250	3	93	25 400	±3.2	12	1 390 000	±2.7	
8..	0.257	0.256	4	70	25 000	±1.6	16	1 470 000	±2.3	
5..	0.256	0.246	6	44	24 500	±1.7	24	1 570 000	±1.5	
8..	0.255	0.501	2	289	26 700	±1.9	8	1 280 000	±3.3	
5..	0.258	0.503	3	201	27 200	±2.2	12	940 000	±1.6	
8..	0.254	0.502	4	143	26 400	±1.5	16	1 440 000	±5.8	
5..	0.254	0.508	6	93	25 500	±2.1	24	1 670 000	±1.9	
5..	0.256	0.762	2	535	31 600	±4.0	8	1 710 000	±0.7	Lengthwise
5..	0.257	0.761	3	335	29 400	±1.1	12	1 730 000	±1.8	
5..	0.255	0.764	4	237	28 600	±0.6	16	1 860 000	±4.6	
5..	0.257	0.764	6	166	29 700	±2.1	24	2 010 000	±3.6	
8..	0.258	0.996	2	740	33 600	±1.8	8	1 760 000	±0.8	
5..	0.257	1.000	3	470	32 000	±1.2	12	1 770 000	±2.5	
5..	0.254	1.000	4	333	31 200	±2.5	16	1 850 000	±3.2	
5..	0.257	1.003	6	225	30 700	±0.8	24	1 940 000	±1.2	
5..	0.257	0.253	2	181	33 100	±2.4	8	1 730 000	±2.1	
5..	0.257	0.249	3	116	31 800	±1.9	12	1 860 000	±3.8	
5..	0.257	0.250	4	85	30 800	±1.3	16	1 880 000	±1.6	
5..	0.258	0.256	6	56	30 500	±1.0	24	2 100 000	±1.0	
8..	0.256	0.493	2	352	32 300	±1.3	8	1 530 000	±2.7	
5..	0.256	0.504	3	231	31 500	±2.0	12	1 170 000	±3.9	
8..	0.256	0.500	4	173	31 700	±1.5	16	1 860 000	±3.7	
5..	0.256	0.503	6	111	30 400	±1.7	24	2 100 000	±2.2	
5..	0.256	0.766	2	480	29 000	±2.2	8	1 310 000	±2.1	Crosswise
5..	0.255	0.762	3	299	27 600	±2.9	12	1 360 000	±1.2	
5..	0.255	0.763	4	220	25 800	±3.6	16	1 460 000	±6.3	
6..	0.257	0.761	6	136	24 100	±2.3	24	1 470 000	±1.7	
9..	0.256	1.001	2	715	27 700	±2.4	8	1 190 000	±6.8	
7..	0.257	0.999	3	389	26 800	±1.6	12	1 330 000	±2.2	
5..	0.257	1.001	4	292	26 400	±2.6	16	1 560 000	±5.5	
5..	0.258	1.001	6	186	25 000	±3.0	24	1 420 000	±3.6	
5..	0.511	0.504	4	697	31 300	±2.8	8	1 750 000	±2.7	
5..	0.509	0.503	6	453	31 300	±1.0	12	1 910 000	±1.0	
4..	0.511	0.500	8	339	30 800	±3.0	16	2 040 000	±1.2	Lengthwise
5..	0.512	0.500	12	219	30 100	±0.6	24	2 090 000	±1.3	
5..	0.512	0.505	8	280	25 400	±1.9	16	1 500 000	±1.5	Crosswise
Grade C Phenolic Laminate										
5..	0.257	0.251	2	110	19 900	±1.6	8	890 000	±1.9	
5..	0.258	0.250	3	69	18 800	±1.4	12	930 000	±3.0	
5..	0.262	0.252	4	52	18 500	±1.5	16	980 000	±1.5	
8..	0.259	0.254	6	33	17 500	±2.2	24	980 000	±3.9	
5..	0.258	0.503	2	225	20 200	±2.0	8	820 000	±3.7	
5..	0.260	0.501	3	148	19 700	±2.5	12	970 000	±4.0	
8..	0.259	0.502	4	104	18 500	±2.1	16	970 000	±5.4	
6..	0.259	0.501	6	65	17 400	±2.4	24	1 070 000	±3.5	
5..	0.274	0.754	2	455	24 000	±2.5	8	920 000	±2.3	Lengthwise
5..	0.274	0.757	3	288	22 900	±3.0	12	1 030 000	±3.6	
5..	0.274	0.757	4	204	21 200	±1.5	16	1 070 000	±2.4	
5..	0.275	0.759	6	131	20 700	±2.0	24	1 100 000	±1.7	
5..	0.272	0.996	2	587	23 900	±2.3	8	920 000	±3.3	
5..	0.269	1.002	3	379	22 500	±5.1	12	970 000	±2.1	
5..	0.272	0.999	4	263	21 300	±2.3	16	1 050 000	±1.6	
5..	0.273	1.001	6	168	20 200	±2.7	24	1 120 000	±6.6	
5..	0.263	0.251	2	138	23 900	±2.0	8	1 040 000	±3.0	
5..	0.260	0.253	3	80	21 000	±2.2	12	960 000	±0.7	
5..	0.261	0.245	4	60	21 500	±2.5	16	1 070 000	±1.9	
8..	0.262	0.251	6	40	21 200	±2.2	24	1 190 000	±2.4	
5..	0.261	0.502	2	271	23 900	±1.6	8	940 000	±2.5	
5..	0.261	0.501	3	165	21 800	±3.2	12	1 000 000	±3.1	
8..	0.262	0.499	4	125	22 100	±2.3	16	1 090 000	±2.3	
8..	0.262	0.502	6	78	20 400	±3.9	24	1 150 000	±1.7	
5..	0.275	0.758	2	389	20 500	±1.9	8	890 000	±0.8	Crosswise
5..	0.273	0.762	3	247	19 600	±1.6	12	960 000	±3.0	
5..	0.275	0.761	4	180	18 900	±2.0	16	970 000	±1.7	
5..	0.275	0.766	6	117	18 200	±1.5	24	1 050 000	±1.7	
5..	0.262	1.000	2	548	24 000	±0.9	8	940 000	±3.2	
5..	0.261	1.000	3	332	23 400	±4.2	12	970 000	±1.3	
5..	0.258	0.998	4	225	20 400	±1.9	16	990 000	±3.3	
5..	0.274	0.999	6	150	18 000	±0.9	24	1 000 000	±1.2	
5..	0.533	0.501	4	535	23 400	±1.8	8	1 090 000	±1.8	
5..	0.515	0.503	6	310	21 000	±2.6	12	1 120 000	±3.2	
5..	0.530	0.500	8	256	21 900	±0.5	16	1 250 000	±1.1	Lengthwise
5..	0.529	0.503	12	160	20 400	±0.7	24	1 300 000	±1.9	
5..	0.522	0.503	8	203	17 900	±2.7	16	1 070 000	±0.8	Crosswise
Vulcanized Bone Fibre										
5..	0.256	0.495	2	259	24 000	±1.9	8	900 000	±0.8	
5..	0.257	0.518	3	165	21 600	±1.1	12	1 140 000	±7.4	
5..	0.255	0.502	4	119	21 900	±2.5	16	1 200 000	±2.4	
5..	0.257	0.490	6	77	21 200	±1.8	24	1 220 000	±3.5	
5..	0.254	0.754	2	363	22 100	±2.6	8	930 000	±2.5	
5..	0.256	0.755	3	242	21 900	±2.1	12	1 230 000	±2.6	
5..	0.256	0.758	4	180	21 800	±1.4	16	1 210 000	±2.9	Lengthwise
5..	0.254	0.766	6	117	21 100	±0.7	24	1 240 000	±1.7	
5..	0.257	0.991	2	481	22 400	±1.2	8	920 000	±7.7	
5..	0.258	0.993	3	316	21 600	±2.1	12	1 290 000	±6.0	
5..	0.255	0.991	4	232	21 700	±1.6	16	1 140 000	±0.7	
5..	0.257	0.989	6	148	20 300	±2.6	24	1 220 000	±1.8	
5..	0.253	0.496	2	178	16 900	±1.4	8	650 000	±5.7	
5..	0.259	0.496	3	118	15 900	±2.0	12	810 000	±3.6	
5..	0.256	0.498	4	85	15 400	±0.5	16	850 000	±2.5	
5..	0.255	0.496	6	54	15 100	±1.0	24	820 000	±1.0	
5..	0.256	0.756	3	176	16 100	±1.5	12	950 000	±6.8	
5..	0.258	0.739	4	128	15 300	±1.2	16	750 000	±3.3	Crosswise
5..	0.259	0.753	6	84	14 900	±0.7	24	800 000	±3.4	
5..	0.259	0.993	2	362	16 300	±1.9	8	600 000	±4.4	
5..	0.257	0.994	3	234	15 900	±2.4	12	800 000	±6.3	
5..	0.256	0.994	4	171	15 800	±1.3	16	750 000	±3.3	
5..	0.260	0.988	6	109	14 700	±1.5	24	800 000	±3.6	

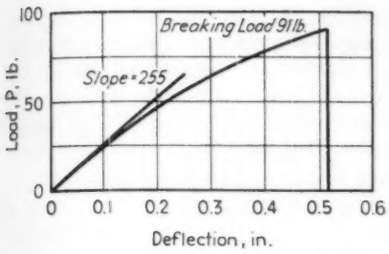


Fig. 5.—Typical Load-Deflection Diagram Grade X Phenolic-Laminate, Tested Lengthwise.
Nominal size: 8 by ½ by ¼ in. Span-depth ratio: 24 to 1.

The rate of crosshead motion was maintained as close as possible to this calculated value by manual control using a dial indicator and stop watch. Previous tests indicated a considerable variation in ultimate flexural strength and modulus of elasticity with speed of testing but this variable was not studied in the present series.

At least five and, in numerous cases, as many as ten samples (where greater variation of breaking load was noted) were successively tested under identical conditions of operation. All samples were carefully aligned flatwise on Sonntag supports with contact edges rounded to a radius of ⅛ in., any burr resulting from the cutting operation having previously been carefully removed from the sample with sandpaper. The thickness and width of each specimen were measured to the nearest 0.001 in., the span to the nearest 1/64 in.

Each sample was tested as a simple beam loaded at the center, the loading nose being identical in shape and dimensions with the end supports. Since the materials tested were relatively hard and since inspection showed that indentation was negligible at the loads encountered, effect of indentation on total deflection was not an appreciable factor.

Results

The observed data and calculated results are summarized in Table I. In view of the voluminous amount of data obtained and in the interests of economy of space, only average values are presented here. The greatest ranges of variables were covered with ¼-in. thick sheet. Sufficient ½-in. phenolic stock was not conveniently available in as great a variety of widths, but the few data given are useful for purposes of comparison. Data on 1/16, ⅛, and 1-in. depths will be presented subsequently.

The ultimate flexural strength (modulus of rupture), S, was computed for each specimen from the measured dimensions and breaking load according to the formula:

$$S = 3PL/2bd^2 \quad \ldots\ldots\ldots (2)$$

where:

b = width of beam as tested in inches,
P = load in pounds, and
S = maximum fiber stress in pounds per square inch.

This formula applies only to materials for which the maximum fiber stress remains linearly proportional to strain up to the point of rupture and consequently cannot be rigorously applied to the type of materials studied. Lacking an exact relationship, however, it has been applied as a convenient means of reporting the flexural characteristics of a material under various conditions of test.

The modulus of elasticity was computed from the formula:

$$E_B = \frac{L^3}{4bd^3}\left(\frac{P}{Y}\right) \quad \ldots\ldots\ldots (3)$$

where:

E_B = modulus of elasticity in bending in pounds per square inch, and
(P/Y) = slope of initial straight line portion of load-deflection curve in pounds per inch deflection.

The slope of the tangent to the load-deflection curve is obtained from the initial portion of this curve as automatically traced by the stress-strain recorder for each specimen. A typical load-deflection diagram is shown in Fig. 5.

Although the values of ultimate strength and of modulus of elasticity are reported as the mean of at least five determinations, the average deviation expressed as per cent are also given. In the case of both properties, the average deviation from the mean of all samples tested are generally well below ± 3 per cent. This is striking evidence of the precision with which data were taken and lends added confidence to the results obtained.

Discussion

Effect of Span-Depth Ratio:

The effect of span-depth ratio on the flexural strength is shown in Fig. 6 where average values of S are plotted *versus* L/d on semi-logarithmic scales. The advantage of using a logarithmic ordinate in this case lies, as is well known, in the fact that equal linear increments on such a scale represent equal percentage changes in the variable plotted. This obviates the sometimes misleading pictorialization frequently resulting from use of arithmetic scales. The average deviations are shown in several cases by small vertical lines drawn above and below the data points. They are

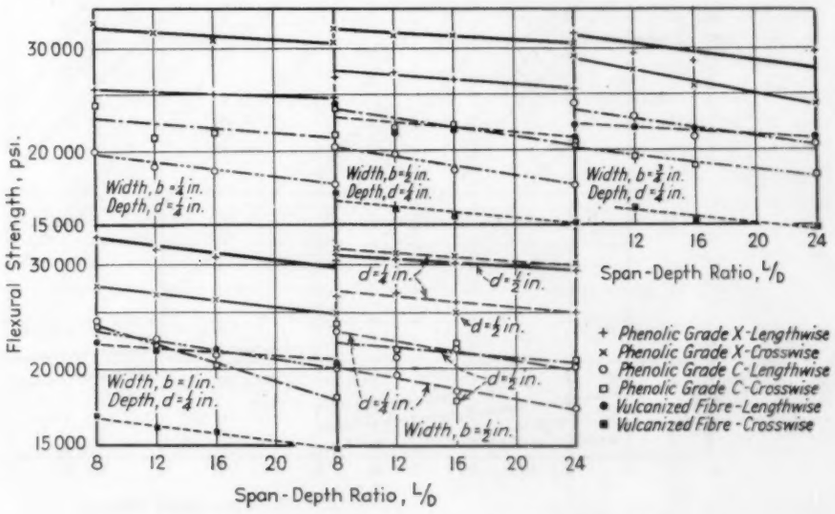


Fig. 6.—Flexural Strength *versus* Span-Depth Ratio.

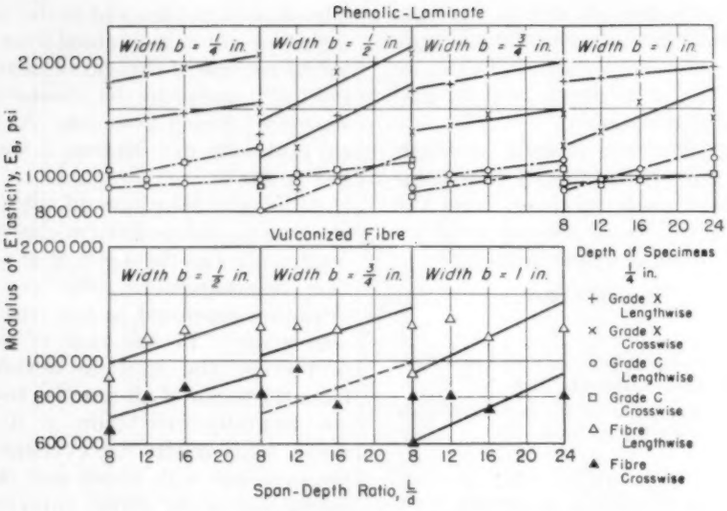


Fig. 7.—Modulus of Elasticity *versus* Span-Depth Ratio.
Depth of specimen : ¼ in.

not shown for all of the data plotted since the same or smaller order of deviation applies approximately to all the tests described.

It is of interest that, in the case of every material tested, there is, in general, a decrease in ultimate flexural strength, S, with increasing span-depth ratio. The rate of decrease, furthermore, is not the same for all samples, but appears to depend both on the nature of the material and on the direction in which the sheet is tested. The few data on ½-in. thick phenolic also vary in this manner as shown in Fig. 6.

Effect of Width:

In the instance of the phenolic-laminate, the data show an anomalous trend with respect to increasing width. Specimens cut lengthwise of the sheet exhibit an increasing flexural strength with increasing width while values for those cut crosswise decrease with increasing width. Vulcanized fibre appears to be more consistent in this respect, particularly at the higher span-depth ratios. The variation of strength with width of specimen could have been shown more directly by using width as a parameter in Fig. 6. This procedure was not feasible, however, without use of an expanded scale for flexural stress, since the data would have fallen very close together.

Modulus of Elasticity:

The values obtained for the modulus of elasticity as a function of span-depth ratio are shown in Fig. 7. Here the modulus is found to increase with increasing span-depth ratio, despite the fact that the data for fibre appear to be less consistent and to scatter more widely than the phenolic. For a given span-depth ratio, however, the modulus increases with increasing width in the case of phenolic specimens cut lengthwise and decreases with increasing width in the case of those cut crosswise of the sheet. The modulus appears less dependent on width in the case of fibre.

The anomalous variation in values computed for the modulus of elasticity with increasing span-depth ratio cannot be satisfactorily explained at this time. Factors such as indentation at the loading edges,

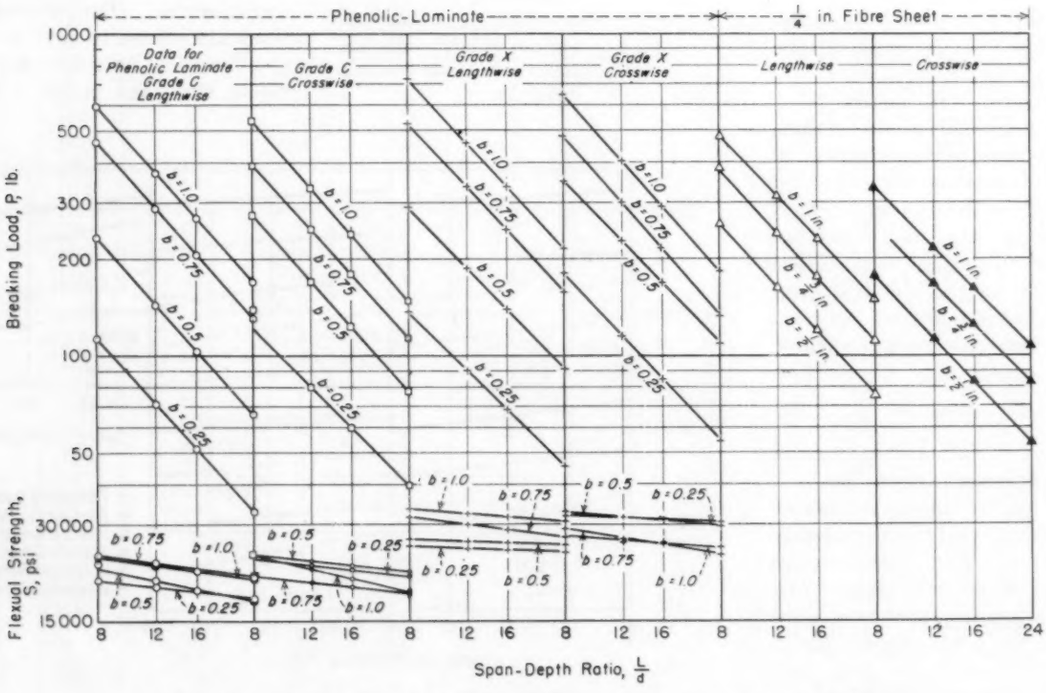


Fig. 8.—Breaking Load and Flexural Strength *versus* Span-Depth Ratio.

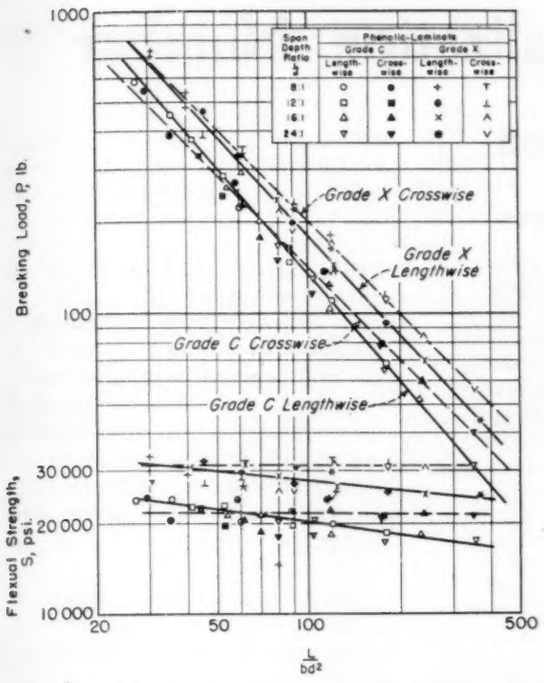


Fig. 9.—Breaking Load and Flexural Strength *versus* L/bd^2.

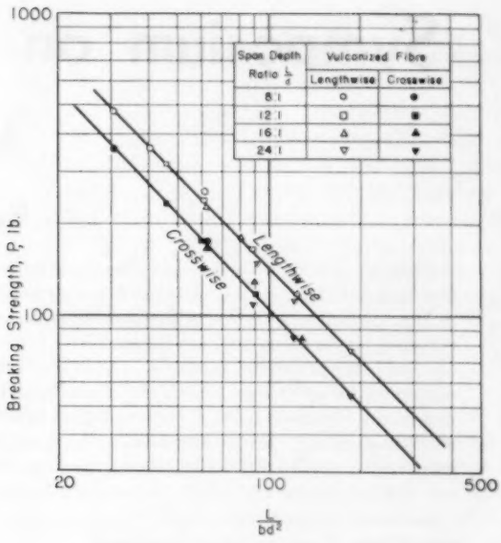


Fig. 10.—Breaking Load *versus* L/bd^2.

take-up in the threads of the machine and low sensitivity of the autographic chart may contribute to this effect. Since the rate of crosshead motion increases with span-depth ratio, according to Eq. 1, it is possible that the use of increased testing speeds may account at least in part for this variation. A study of these different factors is currently being undertaken.

Correlation of Observed Data:

The values of modulus of rupture and of modulus of elasticity, were, as previously pointed out, computed from formulas derived for elastic materials. Since these formulas are known not to hold for plastics, it is of interest to correlate the observed data solely on the basis of the variables measured. A number of different methods of plotting were tried, two of which are shown in Figs. 8 and 9. Here the breaking load, P, is plotted on logarithmic paper *versus* span-depth ratio, L/d, using width as a parameter. The remarkable consistency of observed data is clearly shown. Width as a parameter is eliminated by plotting P *versus* L/bd^2 as shown in Figs. 9 and 10. The abscissae may here be thought of as the product of span-depth ratio and cross-sectional area normal to length. Since this group occurs in the formula for modulus of rupture, this method of plotting can be looked upon as a test of the application of the formula for these materials. The curves of Figs. 9 and 10 show the formula not to apply in all cases since the breaking load here is found to be a power function of L/bd^2, that is, of sample dimensions. Calculated ultimate flexural strength is shown plotted in the lower portion of one of these figures against the same group for purposes of comparison.

In the case of the laminated phenolic tested crosswise, it is of interest to note that the slope of the P *versus* L/bd^2 curves is very close to -1, that is, S is essentially constant. The latter fact is also evident from the S *versus* L/bd^2 curves which, for the crosswise tests, have slopes essentially equal to zero. Samples tested lengthwise exhibit greater deviation, the slopes for grades X and C being about -1.09 and -1.17, respectively. Slopes for the fiber tested lengthwise and crosswise are -1.08 and -1.04, respectively. An empirical expression relating breaking load to specimen dimensions can be obtained from these data having the form

$$P = C(L/bd^2)^{-n} \quad \ldots\ldots\ldots (4)$$

where values of the constant C and exponent n depend only upon the composition and direction of the specimen.

It must be remembered that Eqs. 2 and 3 are derived on the following assumptions: "that the beam is symmetrical, initially straight, homogeneous, of material having equal stiffness in tension and compression, that it is not stressed above its elastic limit by the load, that the bending is slight and that the plane of the external forces coincides with a plane of symmetry."[6] It is evident, therefore, that these formulas cannot be expected to apply to plastic materials, particularly at the point of rupture. The demonstrated deviation of the exponent n from the theoretical value of unity by as much as 17 per cent is proof that the flexure formula must be used with great care.

The data presented here, although restricted to but three types of materials, indicate in a general way the effect of the test variables on the flexural characteristics of these plastics and serve to predict the trends which can be expected from the test method utilized. This study emphasizes a need for similar investigations on other materials and a yet more fundamental approach to plastic behavior under carefully controlled test conditions.

Acknowledgment:

The authors gratefully acknowledge the encouragement and helpful suggestions of A. P. Colburn, G. E. Landt, E. O. Hausmann, G. H. Mains, S. W. Place, and F. L. Stiegler during the course of this investigation.

[6] J. B. Johnson, "Materials of Construction," Eighth Ed., John Wiley & Sons, Inc., New York, N. Y. (1939).

Symposium on Neutralization Number

Introduction

By H. P. Ferguson[1]

EDITOR'S NOTE: It is believed this symposium, held during the January meetings of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants in Detroit, will be of rather widespread interest not only to petroleum technologists but to many who are concerned with the varied uses of lubricating oils and other petroleum products. As H. P. Ferguson, the chairman of the subcommittee in charge, points out the material has been compiled from viewpoints expressed by many technologists in different industries. To an increasing extent, the Society's technical committees are facilitating the preparation of material which should result in a better understanding not only of the scope of a test but particularly a better evaluation of the results. Committee D-2 and other A.S.T.M. groups have prepared reports on the significance of tests of products covered. We are indebted to Mr. Ferguson for the work in planning the symposium, getting the authors' material compiled as shown in the pages which follow, and doing it with a very minimum of delay at a time when time for such work is at a premium.

DURING the winter meeting of Committee D-2 on Petroleum Products and Lubricants, Subcommittee XIII on Neutralization Number and Saponification held a Symposium on Neutralization Number. As planned by the subcommittee, it was hoped that answers to the following questions could be obtained.

1. Do the present methods for determining neutralization numbers give the engineer and petroleum technologist the kind of information desired with respect to new and used lubricating oils?

2. If they do not, what information is desired, and wherein do the present methods fail?

3. Can the present methods be modified or can new methods be devised to give this information?

It was recognized that methods which might be entirely satisfactory in one field may be inadequate in a closely related field. Consequently, it was decided to canvass independently the views of:

(*a*) the Industrial Engineer,
(*b*) the Turbine Engineer, and
(*c*) the Automotive Engineer.

The response to the excellent papers presented was enthusiastic, and it is hoped by the subcommittee that publication of the papers will stimulate further thinking on the subject. The papers have been abstracted and edited by the chairman to eliminate duplication, but otherwise are essentially as presented by the authors.

[1] Chairman, Subcommittee XIII on Neutralization Number and Saponification of Committee D-2 on Petroleum Products and Lubricants. Head, Refinery Operating Control, The Standard Oil Co. (Ohio), Cleveland, Ohio.

Neutralization Number from the Viewpoint of the Industrial Engineer

By C. L. Pope[1]

INDUSTRY in general uses neutralization number of petroleum products in various ways, and places many interpretations upon it. This report is the result of twenty-three replies of a total of sixty-two invitations to participate in this symposium. Replies were received from oil refiners, chemical industries, steel mills, utilities, equipment manufacturers, government departments, railroads, bearing manufacturers, and research and testing laboratories.

Of those replying to the questionnaire, all indicated they used neutralization number for spindle, electric motor, ring oiled bearing, ball and roller bearing, instrument, refrigeration, hydraulic, transformer and switch, gear, compressor and process oils.

In the case of steam cylinder, enclosed gear, cutting, E.P. and similar oils, in general compounded, several replies indicated that neutralization number was not significant. Most all the replies indicated that they used the color-indicator method for new non-additive types of oil and found the method adequate. Many modifications in the technique of running the neutralization number were received.

The replies received indicated few industrial users had as yet installed the equipment for neutralization number by electrometric titration.

A cross-section of industrial opinion on neutralization number may best be furnished by a series of quotations from letters received. The replies have been divided into four groups: (1) new non-additive type oils, (2) new additive type oils, (3) used non-additive type oils, (4) used additive type oils.

New Non-Additive Type Oils:

Since neutralization number is included in most specifications issued by government agencies, industrial organizations, and other consumers, it was interesting to receive the comments on its use for new non-

[1] Lubrication Engineer, Eastman Kodak Co., Rochester, N. Y.

additive type products. The maximum permissible neutralization number for this type of product ranged from 0.02 to 0.15, with one company actually permitting as high as 0.40. Several writers stated they felt that neutralization number on new oils had outlived much of the usefulness it had in former days. It was felt to be a throwback to the time when a simple test was desirable for the purpose of detecting traces of corrosive acid or alkali which the refiner had failed to remove completely from his product. However, the writers did not advocate the discontinuance of the test, but rather pointed out that by itself the test is by no means an adequate basis on which to judge a new oil. Some writers felt that it was not considered an important physical characteristic, but simply served as a refinery control and one company actually felt that no check was necessary since they purchased branded products only. A few companies felt that the neutralization number should be included in the purchase specifications only to the extent of requiring that shipments of the same brand should not vary more than ±10 per cent from the established value for that brand.

New Additive Type Oils:

It was interesting to note that the majority of users differentiated between the value expected of a non-additive oil and the additive type. Five replied they did not differentiate and one raised the maximum permissible neutralization number for additive types to 0.13, compared to 0.05 for non-additive oils. Reasons were given for differentiating, but none for not differentiating.

One writer felt that if a differentiation between additive and non-additive type oils were made, a stumbling block in the way of developing superior additives would be removed. For some reason a slightly alkaline additive oil does not seem to be so objectionable to the consumer as one that shows an acid reaction, however beneficial the acid-bearing material may be in the performance of the oil. A consensus was that each type of oil requires a different criterion since one additive type oil may be alkaline, while another may have an initially high acidic neutralization number. It would seem from the data that industrial users by and large expect unusual neutralization numbers in additive type oils and will not object if it can be demonstrated that such oils are superior for some services to conventional non-additive oils.

Used Non-Additive Type Oils:

All but two replying to the questionnaire reported that neutralization numbers were run regularly on oil systems subject to deterioration of oil. Maximum permissible values ranged from 0.20 to 2.0. One reported a very low limit of 0.08 maximum for circulating oil to clean ball bearings and two reported no maximum limits. The maximum limit for the majority was between 0.7 and 1.0.

Twenty-five per cent use the rate of increase of neutralization number, 50 per cent, a maximum established limit, and 25 per cent use both for guidance. About 70 per cent reported some degree of correlation exists between neutralization number and sludge deposits. However, while agreeing that some degree of correlation might be found, most writers also admitted that the materials of construction, humidity, and temperature influenced the deposition of sludges at a given neutralization number. It was agreed that any such correlation can only be set by experience based on use of certain oils. However, for a given lubricant used in different units of identical design, the relationship may be so influenced by operating conditions and mechanical setup that it is no longer apparent. An inverse relationship sometimes is observed. Thus, technical white oils may attain a high neutralization number which in no wise may be interpreted as a forerunner of sludge.

Some writers felt that there was no relationship between neutralization number and sludge formation. One, for example, stated that since the neutralization number does not identify the acidic component, and the factors influencing the type of acidic component formed are not always recognized, exceptions were found to sludge formation and neutralization number. An example of this is the case of a heavy medium turbine oil used in hydraulic systems which has repeatedly permitted sludge deposits when the neutralization number reached about 0.75. However, this same oil when used in a few gear cases reached a neutralization number of 3.0 to 5.7 in two weeks of operation at 130 F. without sludge formation.

Since the A.S.T.M. method D 663[2] on acid and base number states that there is no known relationship between corrosive acids and acid number, it was interesting to receive the reactions of various industrial users. Ten replies actually indicated that they felt there was no correlation, but five offered comments on the subject. One writer, while admitting there was no correlation between neutralization number and corrosion of high lead bronze, babbitt and cadmium silver bearings, felt that a slight acidity appears to protect the ferrous materials from rusting to a greater degree than a very low neutralization number. Other writers agree that any correlation existing was a specific one and was between a non-ferrous alloy and neutralization number, but not between ferrous materials and neutralization number.

Used Additive Type Oils:

The questionnaire showed eight differentiated in the use of neutralization number between additive and non-additive used oils, five did not, and one desired information on the subject. The comments in general were similar to those received on the use of neutralization number for new additive type products, and for the most part can be stated as requiring a different criterion for each type of additive oil.

There seemed to be universal agreement that neutralization number by itself could not be used to evaluate a used oil, either additive or non-additive type, unless considerable experience with a given product in a given service had been established. There did not appear to be any general agreement on the other tests that should be used in conjunction with neutralization number in order to make the interpretation satisfactory. Tests which are being used include interfacial tension, precipitation number, sa-

[2] 1944 Book of A.S.T.M. Standards, Part III, p. 1198.

ponification, chloroform solubles, viscosity, color, ash, demulsibility, sludge content, power factor, and dielectric strength. The use of power factor and dielectric strength with neutralization number appears to be limited to insulating oils.

In conclusion it is apparent that the colorimetric method D 663[2] has been satisfactory to industry for light-colored oils and is serving to help them with their lubrication problems. The adoption of the electrometric method D 664[3] has not been very wide in industry principally because of the nature of the equipment and the high order of skill demanded for reliable use of the equipment. Furthermore, it was felt that most used industrial oils are discarded before they are dark enough to interfere with a colorimetric determination.

The neutralization number limits for new non-additive oils seem to be well established in industry, and it is encouraging to note that quite a few users do not wish to limit a refiner to a given maximum neutralization number if a suitable product can be produced. Industry in general does not appear to be well versed in the use and behavior of additive type oils in service. Some users permit higher neutralization numbers with these oils than found in non-additive oils and expect unusual neutralization numbers in service. Others make no differentiation. There seems to be general agreement throughout industry that neutralization number can only be correlated with sludge deposits or correlated under very limited conditions.

[2] 1944 Book of A.S.T.M. Standards, Part III, p. 1202.

Neutralization Number from the Viewpoint of the Turbine Engineer—I

By F. C. Linn[1]

Oil is used in a turbine lubricating system primarily to form a liquid film between the rotating shaft and the stationary bearings. In performing this function it also must meet a number of secondary requirements. Some of these are:

(*a*) It must prevent rusting throughout its useful life with water present.

(*b*) It must remain neutral so as not to attack materials normally used in the lubricating system nor form sludges which will deposit and clog the lubricating system.

(*c*) It must not emulsify with water.

(*d*) It must not foam excessively.

(*e*) The viscosity at operating speed and temperature must be low to give minimum power loss.

The main purpose for developing and adopting test procedures is to predetermine when these secondary requirements will no longer be met and thus prevent the use of the oil for its primary purpose.

Oils should be tested periodically during service to determine their instantaneous condition and to predict their useful life. The neutralization number and other tests will be considered with this in view to determine their merit in assisting oil companies and turbine operators in evaluating new and used oils.

The neutralization number of an oil is the number of milligrams of potassium hydroxide required to neutralize 1 g. of sample when tested in accordance with A.S.T.M. Tentative Method of Test for Acid and Base Numbers of Petroleum Products by Electrometric Titration (D 664—44T).[2] In itself it is nothing more than a measure of the total amount of the acidic constituents present in the oil. It does not tell what acids are present, whether they are organic or inorganic, whether they are corrosive or non-corrosive, or whether they are the result of oxidation of the oil or from contaminating sources. However, to both refiner and user, maintenance of the neutralization number within restricted limits is one of several means of assuring uniformity of composition and characteristics among successive batches of new oil. It may not be any indication that the supplier has made a change in his oil.

On used oils no absolute limits of neutralization number have been established as to when it should be discarded. In the case of uninhibited oils the rate of rise in neutralization number is an indication of the speed with which oxidation has taken place. A gradual rise with time is a normal condition which can be expected. However, a rapid rise is indicative that something is wrong and that an investigation of the equipment should be immediately made. A plot of the neutralization number *versus* time is a measure of the rate of oxidation of the oil and when used in conjunction with other test information helps to determine when the oil should be sweetened or discarded.

An oil with low neutralization number may not be satisfactory for continued use, however. Mr. Pope[3] writes, "In one case apparently a weak acid badly etched the steel shaft without showing any increase in neutralization number. We believe that the acid was consumed as fast as it formed so that the neutralization number did not reflect anything unusual." The corrosive action of low boiling point acids (formic, acetic, and propionic) was presented by Dantsizen.[4]

In the case of inhibited turbine oil the use of the neutralization number test, to determine the inhibition period, is not satisfactory due to the small change in neutralization number between the time it is first put into service and when the inhibitor has been used up.

The neutralization number test is simple, reproducible, and is used by most laboratories to assist in determining the condition of the oil.

[1] Chairman, Technical Committee C on Turbine Oils of Committee D-2 on Petroleum Products and Lubricants. Turbine Engineering Division, General Electric Co., West Lynn, Mass.

[2] 1944 Book of A.S.T.M. Standards, Part III, p. 1202.

[3] Eastman Kodak Company, Rochester, N. Y.

[4] C. Dantsizen, "Lubrication of General Electric Turbines," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 63, No. 6, p. 491 (1941).

R. G. Call* writes, regarding the use of neutralization number test for inhibited oils,

"We believe this test to be of little value to the laboratory or the operator as an indication of the oil's condition.

"The changes that occur in inhibited oils, even after years of operation, are so slight that they cannot be measured readily by this test.

"The interfacial tension test is capable of following these changes as they occur, and will predict a breakdown of the oil long before there is a change in neutralization number.

"In laboratories where equipment is not available for making this test, we believe the saponification number to be a good substitute as there is direct correlation between this value and interfacial tension.

"Industry will welcome another test if it is capable of determining the instantaneous condition of the oil with respect to oxidation."

From the above it is seen that tests other than neutralization number are being used with a greater feeling of security than is neutralization number, particularly with inhibited oils. Other tests which have been in successful use, other than those mentioned above, are:

(*a*) Precipitation number A.S.T.M. Methods D 91 – 40.[5]

(*b*) Peroxide content.

(*c*) Viscosity increase—the increase in viscosity indicates the formation of noncorrosive acids which will ultimately result in sludge formation.

(*d*) Color.

(*e*) Emulsion tendencies.

(*f*) Sludging tendencies.

Other tests which may be used in evaluating the expected life of the oil are:

(*a*) Periodic determination of corrosive and noncorrosive acids in the oil.

(*b*) Periodically run oxidation tests on the used oils in accordance with Proposed Method of Test for Oxidation Characteristics of Steam-Turbine Oils,[6] to determine the remaining inhibition period.

There have been some recommended changes in this procedure which the committee is studying at this time and with these changes the useful life remaining in the oil should be able to be determined with a high degree of accuracy. Mr. Pope has been successfully using a modified oxidation test as reported in the ASTM BULLETIN.[7]

The number of replies from members of Technical Committee C and Subcommittees on the above subject, indicates that the majority of the members are interested in seeing tests devised which when used periodically will determine the remaining useful life of the oil.

In conclusion it appears that the use of the neutralization number test has been satisfactory in the past to assist in determining the remaining useful life of non-inhibited oils in service. However, it appears not to be satisfactory for the inhibited oils which are rapidly coming into use. We would, therefore, recommend that additional work be done by the A.S.T.M. to devise tests which can be used by the supplier and the user in determining the amount of useful life remaining in an oil during its service.

* American Gas and Electric Service Co.

[5] Standard Methods of Test for Precipitation Number of Lubricating Oils (D 91–40), 1944 Book of A.S.T.M. Standards, Part III, p. 222.

[6] *Proceedings*, Am. Soc. Testing Mats., Vol. 43, p. 275 (1943).

[7] C. L. Pope and D. A. Hall, "Oxidation-Corrosion of Lubricating Oils," ASTM BULLETIN, No. 121, March, 1943, p. 25.

Neutralization Number from the Viewpoint of the Turbine Engineer—II

By G. H. von Fuchs[1]

IF WE were to choose among existing, well-established laboratory tests to determine the end of the useful life of an oxidized oil, as in the proposed test for oxidation characteristics of steam turbine oils[2] or in service, we should find the saponification number to be far more significant. However, it is unlikely that any single oil property can take the place of the neutralization number in its various present applications and misapplications.

It is known that oxidation is the major cause of oil deterioration, while peroxides, free and combined acids, oil-soluble resins, and sludge merely represent different stages of the oxidation process. What we are really interested in is the effect these oxidation products have on oil performance.[3]

Harmful effects of turbine oil oxidation are poor demulsibility, tendency to foam, and sludge formation. There is sufficient evidence to believe that these effects are principally due to soaps of the acids rather than the free acids themselves. Furthermore, the effective (harmful) concentration of these soaps is usually so low that neither a conventional neutralization number nor a saponification number is able to detect them.

As long as tin-base babbitt bearings are used in steam turbines, corrosion of alloy bearings, whether measured by neutralization number or by some other means, is not a problem, but would certainly become serious with lead-base babbitt. Wilson of Allis-Chalmers described a case where rapid oil breakdown, attack on bearings, and rusting of the lubricating system, both below and above the oil level, occurred in an old turbine a few months after lead-base babbitt bearings were installed. According to the case history furnished by Wilson, this was a wet turbine but no rusting had previously been found. When rust was discovered the water cen-

[1] Consulting Chemist, Shell Oil Co., Inc., Wood River, Ill.

[2] "Proposed Method of Test for Oxidation Characteristics of Steam-Turbine Oils," *Proceedings*, Am. Soc. Testing Mats., Vol. 43, p. 275 (1943).

[3] The increase in viscosity has been proposed as a possible measure of oil deterioration. Here again we have a test which in itself is not overly significant; it does, however, imply a change in the oil which may be caused by loss of light ends or by contamination but which may also be due to oil-soluble oxidation products. It seems that in such a case an increase in saponification number usually precedes the increase in viscosity, while sludge formation follows it. Direct tests for emulsion, foaming, and sludging tendencies are thus far more significant.

trifuged from the oil was decidedly acid (pH 3–3.5). While Wilson does not draw a definite conclusion in this case, he offers the possibility of contamination by gland water (which, however, is normally basic) or by a carbon tetrachloride cleaner (which was said to have been completely evaporated before oil was added to the system). It appears more likely, however, that the acidity in the water was due to a rapid breakdown of the lubricant catalyzed by lead and forming low-boiling water-soluble organic acids. The rust-promoting action of the volatile fatty acids (formic, acidic and propionic) was shown by Mr. Dantsizen several years ago.[4] More recently[5] he also found that while in oxidation tests in the presence of a lead specimen with water absent there was a gradual increase in weight loss with increasing neutralization number, in the tests with water present there was a sharp increase in weight loss of the lead. Neutralization value *per se* is no criterion of oil corrosivity since in many instances the corrosive oil had a neutralization number of 0.2 or less. However, the presence of corrosive acids can often be proved by steam stripping such an oil; the steam condensate is then usually acidic. Lead-base babbitt may give satisfactory service if the oil is kept free from moisture (leakproof seals, venting of oil system) or by using an oxidation inhibited oil.

Most of the preceding discussion refers to conventional uninhibited oils, that is, oils in which oxidation can proceed in more or less normal manner—uninfluenced by additives. In oxidation-inhibited oils acid formation is largely suppressed until the inhibitor is consumed, after which time oxidation proceeds at an acclerated rate.

The Turbine Oil Stability Test[2] has been designed to evaluate the prospective service performance of turbine oils. With this purpose in mind, the test is conducted in the presence of oxygen, water, and metal catalyst. The test is ended when the oil reaches a neutralization number of 2.[6] When rust and oxidation-inhibited oils are observed during this test, remarkable differences become apparent which do not express themselves in neutralization number values. Some oils discolor badly, carry rust in suspension, or start to form aqueous sludge soon after the start of the test. In many such cases the catalyst coils are attacked.[7] The copper coil becomes coated with sludge while the iron coil disintegrates and the aqueous phase becomes clogged with rust. In other cases, the oil foams badly. While to all outward appearances such an oil would be unfit for service, the test may continue for many thousands of hours before a neutralization number of 2 is reached. In certain cases not even a saponification number (determined on a filtered oil sample) shows any indications of oil breakdown. The same oils which cause severe rusting in this test, will pass the A.S.T.M. Tentative Method of Test for Rust-Preventing Characteristics of Steam-Turbine Oil in the Presence of Water (D 665–44 T)[8] when new. Obviously in their present form neither the turbine oil oxidation test nor the rusting test gives a true prediction of oil performance in service. That this is so is evidenced by field experience and is the reason for the reluctance of power plant operators to accept these tests in their oil specifications.

The present turbine oil stability test setup is fundamentally sound and with only minor modifications[9] would be perfectly suitable for predicting the service performance of turbine oils if the evaluation of the test method would include appearance[10] of the oil and the catalyst coils in addition to neutralization and/or saponification number. Severe rusting or sludging should be causes for discontinuing the test even if no corresponding rise in neutralization number, etc., can be observed.

The failure of the neutralization number to evaluate internal-combustion engine lubricants in service has long been realized and in view of a lack of significant laboratory tests, appearance of the testing equipment has been successfully resorted to in evaluating heavy-duty additive-type oils in the 36-hr. Chevrolet and other engine tests.

It is hereby proposed to supplement the present turbine oil stability test by observing the appearance of the oil and testing equipment (catalyst coils, etc.) and also the water phase and by measuring rust and sludge suspension, demulsibility, and foaming tendency of the oil when visual inspections warrant such tests. In this manner critical values could be established which would then evaluate both inhibited and uninhibited turbine oils according to their service performance.

[4] C. Dantsizen, "Lubrication of General Electric Turbines," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 63, No. 6, p. 491 (1941).

[5] Minutes of the meeting of Technical Committee C on Turbine Oils of Committee D-2 on Petroleum Products and Lubricants, January 18, 1944.

[6] The neutralization number was selected as the criterion most generally accepted in turbine oil service while the value of 2 represents a compromise concerning both conventional and oxidation-inhibited oils.

[7] Similar observations were made by C. L. Pope and D. A. Hall, "Oxidation-Corrosion of Lubricating Oils," ASTM BULLETIN, No. 121, March, 1943, p. 25.

[8] 1944 Book of A.S.T.M. Standards, Part III, p. 1283.

[9] Replacement of fritted glass bubbler, which shows a tendency to plug and thus to interrupt oxygen flow, with a straight glass tube.

[10] Observing the appearance of oils in the turbine oil stability test is greatly facilitated by equipping the oil bath with glass windows and internal illumination.

Neutralization Number from the Viewpoint of the Automotive Engineer

By H. R. Wolf[1]

IN PREPARING this paper to present an industry rather than a personal viewpoint, the subject of neutralization number was discussed with a number of designing engineers, lubrication project engineers, chemists and technologists in the automobile industry.

The various technical people in the automobile industry who are

[1] Research Laboratories Division, General Motors Corp., Detroit, Mich.

interested in analytical data on new and/or used oils divide very quickly into two groups; first, the engineers responsible for the design and manufacture of the product and, second, the engineers responsible for the operation of the product in service.

The first group are mechanical engineers interested in neutralization number only as a means of predicting performance or explaining failures that have occurred. This group is generally rather hazy as to the meaning or significance of neutralization number. Some reply that they are not chemists and therefore cannot be expected to interpret the various ramifications of neutralization number. These engineers generally think of neutralization number as a term that reflects the corrosive tendency of an oil. Some in this group insist that neutralization number, in order to be of value to the engineer, must be a quantitative measure of corrosion, and must be expressed as a "go" or "no-go" dimension or property of an oil in the same manner as the diameter or hardness of a piston pin. This, of course, is not the case as is illustrated by the L-4 or Chevrolet 36-hr. engine test data[2] shown in Tables I and II.

Table I shows the engine deposit rating, bearing loss in grams per half-bearing, and the neutralization number on an S.A.E. 30 base oil and on the same oil plus a heavy-duty additive. This addition agent reduced the bearing corrosion from 0.533 g. per half-bearing to 0.044 g., that is, from a value sufficiently high to cause rejection to a value well within the requirements of U. S. Army Specification 2-104B. However, the attendant change in neutralization number was not significant in predicating that bearing corrosion had been rectified.

TABLE I.—CHEVROLET 36-HR. TEST.

S.A.E. 30 Pennsylvania Oil	Base Oil	Base Oil Plus Additive
Engine deposit rating	76	89
Bearing loss, g. per half bearing	0.533	0.044
Neutralization number	1.10	0.74

Table II shows similar data on five different base oils compounded with the same additive. The bearing losses per half-bearing range from 0.044 to 0.075 g., while the neutralization numbers range from 0.74 to 1.32 with no correlation. The data in Table II are representative of a large amount of similar data available from the field and from dynamometer and bench oxidation tests and are responsible for the statement in A.S.T.M. Tentative Methods of Test for Acid and Base Numbers of Petroleum Products by Color-Indicator Titration (D 663–44 T)[3] and by Electrometric Titration (D 664–44 T)[4] that, "No general relationship between corrosive acids and acid number by any method is known."

Occasionally an engineer is assigned the task of reviewing and tabulating laboratory reports on various grades and types of oils operating under different service conditions. It is generally found that little or no correlation between neutralization number and other properties or performance in service exists, and in an endeavor to learn more about neutralization number, a study of the two A.S.T.M. methods may be made. In the color-indicator method, the reagents *react* with the sample, while in the electrometric method the reagents are more versatile and *react* with the sample, are *consumed* by the sample, or *neutralize* the strong acid content of the sample. The engineer does not realize that the chemist has used *react*, *consume*, and *neutralize* interchangeably but assumes that these different terms indicate different degrees of chemical activity.

The automobile engineer may survive the ordeal of reconciling these differences in definitions only to be thoroughly confused when examining the data obtained by the two A.S.T.M. methods on certain types of heavy-duty crankcase lubricants. The data[5] from an unused oil, shown in Table III, illustrate this point.

The engineer is worried by the high acid number reported by the color-indicator titration method, and is doubly worried by the much higher acid number reported by the electrometric titration method. But he is confused beyond recovery when he learns that the same oil can have both a high acid and a high base number.

When it is explained that the high acid and base numbers in this case are due to the reaction of the heavy-duty oxidation inhibitor and detergent compounds, present in the oil, with both KOH and HCl under the conditions of the test procedure, the engineer immediately wants to apply the acid and/or base numbers or the ratio between the two numbers as a means of determining the reduction or loss of addition agent from the lubricant in service.

When it is further shown that considerable additional analytical data are required to establish the chemical changes that occur during use in an engine; that the different

TABLE II.—CHEVROLET 36-HR. TEST.

S.A.E. 30 Oils Plus Same Additive	Naphthenic	Mid-Continent		Pennsylvania	
Rating	89	90	91	89	89
Bearing loss g. per half bearing	0.075	0.046	0.054	0.068	0.044
Neutralization number	1.14	1.30	0.40	1.32	0.74

TABLE III.

Color-Indicator Titration	Electrometric Titration
Acid Number:	Acid number....3.27
Low.....1.00	Base number....3.34
High.....1.45	
Average.....1.17	

TABLE IV.—USED OIL ANALYSES AND CONDITION OF ENGINE PARTS.

	Oil A	Oil B	Oil C	Oil D	Oil E
	20-W Medium Quality	10-W Highly Refined	10-W Plus Inhibitor	10-W Plus Detergent	10-W Plus Inhibitor and Detergent
Miles	2000	2000	4000	3000	4000
Neutralization number	0.66	7.70	0.46	9.70	0.22
Naphtha insoluble	1.07	0.99	0.48	3.41	0.38
Chloroform soluble	0.87	0.45	0.11	1.75	0.08
Viscosity increase at 100 F	...	174	12	334	12
Engine condition	very dirty	fair	clean	clean	clean
Pistons	stuck	stuck	free	free	free
Varnish	dark	transparent	nil	nil	nil

[2] A. O. Willey, "Base Oil Evaluation for Heavy-Duty Service," *National Petroleum News*, Vol. 35, No. 44, Section 2, November 3, 1943, p. R-503.

[3] 1944 Book of A.S.T.M. Standards, Part III, p. 1198.

[4] *Ibid.*, p. 1202.

[5] Cooperative Test Sample T-3-42, Subcommittee XIII of A.S.T.M. Committee D-2.

types of additives may react with KOH, remain neutral or react with H_2SO_4 or HCl under the conditions of the test; that there is no relationship between acidic and/or basic characteristics and the inhibitor and/or detergent properties; the engineer is ready to discard neutralization number as a test which is of little or no value and which may give misleading results with oils containing additives.

Table IV further illustrates this point. The five oils[6] reported in this table were tested in a Chevrolet engine essentially under the conditions outlined in the L-4 procedure except that the duration of the individual tests varied as noted in the table.

If no information is available regarding the composition of these oils and if it is necessary to give an opinion regarding engine condition based on neutralization alone or in connection with the balance of the used oil analysis, oil D would probably be reported as the poorest of the five oils and certainly would be reported as inferior to oils C and E. As a matter of fact, the engines operating on oils C, D, and E were extremely clean and free from varnish on the piston skirts. The metallic soap in oil D had some catalytic effect on the oxidation of the base oil but prevented the deterioration products from forming engine deposits. On the same basis oil A would probably be reported as highly superior to both oils B and D, whereas judging from engine conditions oil A is slightly inferior to oil B and highly inferior to oil D.

You will recall that it was mentioned that the engineers in the automobile industry may be divided into two groups. We have seen that neutralization number is of little or no service to the first group; it is now in order to see whether neutralization number is of interest to the second group, the engineers who are responsible for the operation of the equipment in service and for the selection of lubricants.

Tables V and VI report the analyses of two oils operated in the same type of gasoline engine equipment under essentially the same type of normal road operation.

[6] H. R. Wolf, "Crankcase Oils for Heavy-Duty Service," *SAE Journal (Transactions)*, Vol. 48, No. 4, April, 1941. p. 128.

TABLE V.—NORMAL ROAD OPERATION—10-W PENNSYLVANIA OIL WITHOUT ADDITIVE.

Miles	Neutralization Number	Naphtha Insoluble	Chloroform Soluble	Conradson Carbon	Ash
0.....	0.04	...	...	...	Nil
1074.....	0.45	0.94	0.24	1.00	0.19
1620.....	0.78	0.92	0.26	1.33	0.19
2266.....	0.80	1.55	0.34	1.92	0.44
2413.....	0.95	1.21	0.29	1.87	0.46
4470.....	0.97	2.67	0.42	3.18	0.76
4948.....	1.14	2.02	0.45	2.29	0.51

TABLE VI.—NORMAL ROAD OPERATION—NAPHTHENIC OIL WITH ADDITIVE.

Miles	Neutralization Number	Naphtha Insoluble	Chloroform Soluble	Conradson Carbon	Ash
0.....	1.21	...	...	...	0.35
449.....	0.83	0.42	0.16	0.58	0.38
1188.....	1.09	0.59	0.16	0.80	0.50
1690.....	1.24	1.31	0.23	1.19	0.57
2262.....	1.24	1.13	0.21	1.52	0.88
2724.....	1.14	1.15	0.18	1.82	0.82

Table V shows that the neutralization number of the uninhibited oil increases rather rapidly through the first half of the test and then more slowly until it reaches the maximum value at the end of the test period. Table VI shows that the particular additive used in this test raises the neutralization number of the unused oil to a value higher than the end value in Table V. During the early part of the test the neutralization number dropped slightly, indicating that some of the inhibitor compound was consumed. The neutralization number then gradually built up to approximately the original value, probably due to the addition of fresh inhibitor in the makeup oil and to some extent to the formation of some organic acid on oxidation of the base oil.

The used oil analyses on six oils[6] run in the GM "71" Diesel engine in substantial accord with the conditions outlined in the L-5 test procedure are shown in Table VII. The tests on the first two oils were stopped at 116 and 91 hr., respectively, due to excessive bearing corrosion and engine deposits. In these cases the neutralization numbers are high and suggest bearing corrosion. The third oil did not oxidize so badly as the first two oils, but the engine failed at 96 hr. because of excessive piston deposits. In the tests on the last three oils, the neutralization numbers remained at relatively low values, the copper-lead bearings were not corroded, and the engines were clean and free from injurious piston deposits. In the test on the last oil the engine was operated for the first 144 hr. without a sludge filter. This accounts for the high naphtha insoluble reported on the 96-hr. sample.

TABLE VII.—ANALYSES OF OILS RUN IN GM "71" DIESEL ENGINE.

Time, hr.	Neutralization Number	Naphtha Insoluble	Chloroform Soluble
8....	0.05	0.17	0.06
55....	0.82	0.34	0.16
116....	2.14	3.06	2.26
25....	0.64	0.45	0.24
68....	2.58	3.18	2.83
91....	3.44	6.98	6.24
24....	0.11	0.33	0.07
72....	0.38	1.07	0.40
96....	0.43	3.04	1.60
100....	0.16	0.19	0.05
205....	0.26	0.18	0.03
305....	0.42	0.52	0.11
501....	0.54	0.11	0.03
757....	0.59	0.16	0.05
97....	0.16	0.30	0.08
206....	0.22	0.38	0.05
353....	0.16	0.33	0.08
530....	0.21	0.44	0.09
96....	0.11	1.02	0.54
192....	0.16	0.10	0.05
312....	0.16	0.09	0.04
408....	0.22	0.12	0.05
500....	0.22	0.28	0.13

The neutralization number data reported in Tables V, VI, and VII are very useful to the engineer in following the changes that take place in service, particularly when information regarding the type and composition of the base oils and addition agents are known.

The marked difference in neutralization number on the same oil[6] from dynamometer and road tests is illustrated in Table VIII. When oxidation occurs the used oil from the engine operated on the dynamometer develops a high neutralization number but the naphtha insoluble matter remains low, while in the used oil from the engine operated on the road the neutralization number remains low and the naphtha insoluble builds up to a high value. This trend has been confirmed in a number of cases in oils that oxidize under the test condi-

tions. This difference in used oil analyses does not necessarily indicate a difference in the character of the oxidation under the two different types of operating conditions but probably indicates a further oxidation and/or polymerization of the acidic compounds to naphtha insoluble resins.

TABLE VIII.—USED OIL ANALYSES ON SAME OIL FROM DYNAMOMETER AND ROAD TESTS.

	Dynamometer	Road
Miles	4000	4770
Neutralization number	4.38	0.83
Naphtha insoluble	0.94	2.11
Chloroform soluble	0.18	0.38
Conradson carbon	2.61	2.65
Ash	0.50	0.65

Some data on the effect of the solvent used in the neutralization number determination are shown in Table IX. The solvents shown cover a wide range and include single and two-phase solutions. With some additives a change in solvent may produce a significant deviation from the mean in neutralization number, but in all cases the lubricants tested were classified in the same general order. A single-phase solution may offer many advantages in working with new, light-colored oils but may fail entirely with dark colored and used oils.

Some additional data using butylcellosolve as a substitute for alcohol in Method D 663–44 T are shown in Table X. With used oil butylcellosolve tends to show a much higher neutralization or acid number. These higher numbers may or may not be significant in studying oxidation of the base oils.

TABLE IX.—EFFECT OF SOLVENT ON ACID AND BASE NUMBERS.

S.A.E. 10-W High VI Oil, Plus Additive as Indicated	A.S.T.M. Method D 663–44 T	Butylcellosolve Water Added, Titrated Hot	Alcohol-Isooctane No Water Added, Titrated Cold	Alcohol-Benzol No Water Added, Titrated Cold
0.25 per cent oleic acid	0.47	0.55	0.52	0.55
	0.52	0.52	0.47	0.59
1 per cent zinc naphthenate	1.22	1.14	1.22	1.43
	1.22	1.18	1.27	1.48
1 per cent sodium sulfonate	0.00	0.00	0.04	0.04
	0.00	0.00	0.04	0.04
1 per cent acetylsalicylic acid	2.79	2.70	2.11	2.24
	2.70	2.70	2.15	2.19
Commercial heavy-duty oil A	−7.38	−7.44	−7.55	−7.22
	−7.44	−7.55	−7.29	−7.22

TABLE X

	A.S.T.M. Method D 663–44 T	Butylcellosolve Substituted for Alcohol	Ratio, B/A
	A	*B*	
New heavy-duty oil B	0	0.08	...
New heavy-duty oil C	1.14	1.25	1.1
Used heavy-duty oil D	1.35	4.72	3.5
Used heavy-duty oil E	1.39	1.86	1.3

Oils D and E contain the same amount and type additive as oil C.

The data given in Tables IX and X are not properly a part of a paper on the viewpoint of the automobile engineer in regard to neutralization number, but they are included with the hope that they might stimulate some committee work that may result in a method that can be handled more readily by the laboratory technician and yield more consistent results in different laboratories

Conclusions

In conclusion, the use of neutralization numbers may be summarized as follows:

1. Neutralization number, *per se*, is very misleading, particularly with the additive type oils.
2. No distinction is made between organic acids formed on oxidation, and additives which react with KOH.
3. Neutralization number cannot be used in drawing conclusions regarding used oils unless a number of other factors are known.
4. Neutralization number can be very useful in connection with other characteristics or tests in identifying certain additives.
5. Neutralization number can be used in following changes which take place in service or in engine tests in known oils.

A Comparison of the Salt Method with A.S.T.M. Method for Determining the Acidity of Lubricating Oils

By C. M. Loane[1]

The determination of acidity in used oils from internal-combustion engines has long been an annoying and controversial problem. The A.S.T.M. Tentative Method of Test for Acid and Base Numbers of Petroleum Products by Color-Indicator Titration (D 663–44 T)[2] was developed to minimize some of the experimental difficulties ordinarily encountered with previously used methods. Although constituting an improvement in some respects, Method D 663 still has some undesirable features. In the course of work on used oils a method, hereinafter called the "Salt Method," was developed in this laboratory, and it has been the practice to determine acidities on used oils from engine tests both by Method D 663 (specified for Ordnance approval tests) and by the salt method. The salt method[3] involves the addition of a saturated, aqueous sodium chloride solution to a used oil-naphtha-alcohol mix to avoid the formation of troublesome emulsions during the titration. It is the purpose of this paper to compare this method and A.S.T.M. Method D 663 on the bases of (1) significance in relation to bearing corrosion and (2) reproducibility.

The Salt Method for Neutralization Number

General:

The chief advantage of the salt method is that its use permits the ready separation of a clear, light-colored alcohol-water layer—even after vigorous shaking at any stage of the titration of highly oxidized oils. However, it does not eliminate the problem of deciding just what shade of pink should be called

[1] Research Department, Standard Oil Company (Indiana), Whiting, Ind.
[2] 1944 Book of A.S.T.M. Standards, Part III, p. 1198.
[3] A similar method was suggested to A.S.T.M. several years ago by the Phillips Petroleum Co.

the end point. The gradual deepening of the indicator color and a more or less fugitive end point are characteristic of any colorimetric titration procedure for samples containing such a variety of weak acids and other oil-oxidation products capable of acid reaction under favorable conditions. In this respect, the salt method offers no improvement over other methods.

The salt method is not thoroughly standardized and doubtlessly modifications could be made that would further improve reproducibility. Since the meeting of Committee D-2 in January, several minor changes in the method have been made.

Outline of Procedure:

Five grams (± 0.1 g.) of the oil to be titrated is weighed into a 250-ml. Erlenmeyer flask, equipped with a ground glass stopper. Twenty milliliters of neutralized naphtha are added and the oil dissolved by agitating. A further addition of 40 ml. of a neutralized, saturated, aqueous solution of NaCl and 40 ml. of neutralized 95 per cent ethyl alcohol is made. The contents of the flask are brought to boiling on a hot plate and boiled gently for 1 min. Phenolphthalein is added and the oil is titrated hot with 0.1 *N* alkali. During the first additions of the alkali, the pink color in the alcohol layer is discharged by swirling the flask.

NOTE 1.—Swirling instead of shaking during the initial stages of the titration is merely for convenience in permitting more rapid determinations.

NOTE 2.—If the naphtha-oil and alcohol-water layers do not readily separate toward the end of the titration, the flask is warmed on the hot plate until separation occurs. This is very seldom required.

When the pink color is no longer rapidly discharged by swirling, the flask is shaken. The titration is continued until a definite pink color persists for 30 sec. after 5 sec. of vigorous shaking. The end point is determined by tilting the flask at a 45-deg. angle and observing the color about ½ in. above the bottom edge of the flask.

CORRELATION BETWEEN ACIDITY AND BEARING CORROSION

Although it is well recognized that there is no direct or general relationship between acidity and rate of bearing corrosion, it is true that by limiting the relationship to oils of the same type, acidity measurements do afford some measure of the extent or probability of bearing corrosion. Chevrolet 36-hr. tests on such a restricted series of oils had been run by our Engine Laboratory.

In this series of tests, data were available for over one hundred oils differing only in (1) the proportions of corrosion inhibitor and detergent or (2) variations in the method of making the additives. A study has been made of the correlation between used oil acidities, as determined by the A.S.T.M. Method D 663–42 T[4] and the salt methods, and bearing corrosion in these tests. Acidities, by both methods at both 16 and 36 hr., are plotted against bearing corrosion in Figs. 1 to 4. Each circle in these figures represents the result from one Chevrolet 36-hr. test.

The results of these correlations can be summarized as follows:

Figure 1.—While all the points do not by any means fall on the curve, there is a definite trend of increased acidity with increased bearing corrosion.

Figure 2.—There appears to be absolutely no relationship between acid number and bearing corrosion.

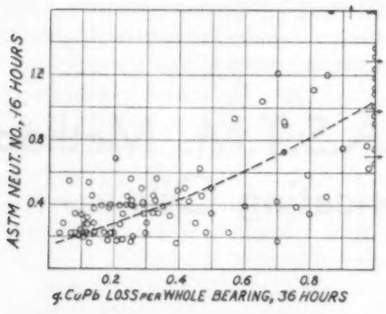


Fig. 1—Chevrolet 36-hr. Tests—A.S.T.M. Method D 663–42 T Neutralization Number (16 hr.) *versus* Bearing Corrosion

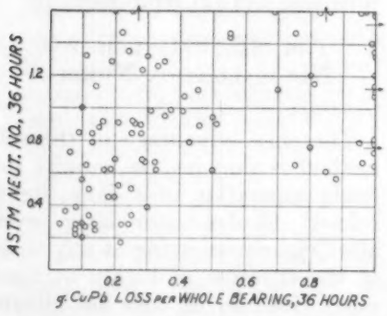


Fig. 2.—Chevrolet 36-hr. Tests—A.S.T.M. Method D 663–42 T Neutralization Number (36 hr.) *versus* Bearing Corrosion.

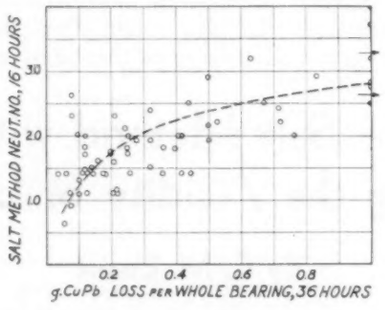


Fig. 3.—Chevrolet 36-hr. Tests—Salt Method Neutralization Number (16 hr.) *versus* Bearing Corrosion

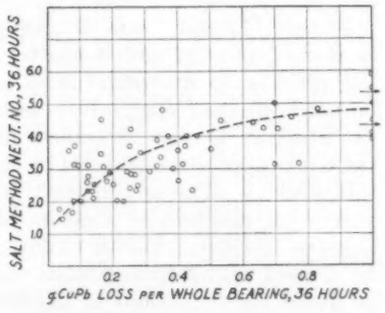


Fig. 4.—Chevrolet 36-hr. Tests—Salt Method Neutralization Number (36 hr.) *versus* Bearing Corrosion

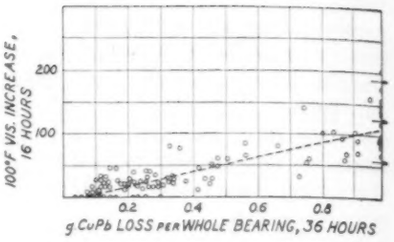


Fig. 5.—Chevrolet 36-hr. Tests—100 F. Viscosity Increase (16 hr.) *versus* Bearing Corrosion

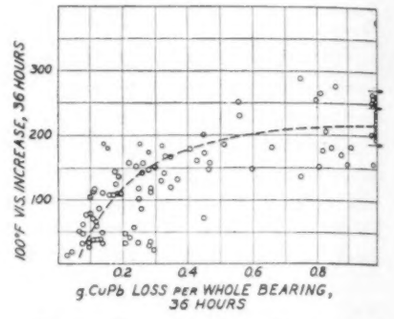


Fig. 6.—Chevrolet 36-hr. Tests—100 F. Viscosity Increase (36 hr.) *versus* Bearing Corrosion

[4] 1942 Book of A.S.T.M. Standards, Part II, p. 954.

Figure 3.—A definite trend, roughly equivalent to that in Fig. 1, is indicated.

Figure 4.—In contrast to the A.S.T.M. Method D 663, 36-hr. acidity results, there is a reasonably good correlation between neutralization number and bearing corrosion.

To orient further the relationship between used oil analyses and bearing corrosion, 100 F. Saybolt viscosities, at both 16 and 36 hr., are plotted against 36-hr. bearing corrosion in Figs. 5 and 6. The viscosity data appear to correlate somewhat more closely with bearing corrosion than do any of the acidity data.

The analytical data used in the figures are subject to some qualification. They were obtained almost entirely on a routine basis by nontechnical personnel lacking extensive experience. Errors have doubtlessly occurred in some determinations far greater than would be expected from inherent faults of the methods. The better showing of the viscosity data may be partly due to the better standardization and simplicity of the method.

However, assuming that the data do represent the average relationship between used oil analyses and bearing corrosion, it can be concluded (1) that the salt method for acidities gives results of somewhat more significance than A.S.T.M. Method D 663 acidity results as regards bearing corrosion, but (2) that an altogether different measure of oil deterioration, namely, viscosity, correlates with bearing corrosion at least as well as acidities by either method. Considering that (1) it is necessary to know thoroughly the nature and performance background of the oil under consideration before any relationship between acidity and bearing corrosion can be established and (2) when these background data are available a totally unrelated measure of deterioration is fully as significant as acidity, it appears unwise to attach great significance to correlation between acidity results and bearing corrosion.

Reproducibility of the Methods

Acidity data, by both A.S.T.M. Method D 663 and the salt methods, on all oils from Chevrolet tests during the past year were available from our engine laboratory. To formulate some idea of the relative reproducibilities of the two methods in the hands of our own technicians, fifty of these samples were rerun by both methods by two other operators. These samples included (1) both 16 and 36-hr. samples, (2) various base oils and additives, and (3) moderately and highly deteriorated oils.

One technician ran check determinations on each sample by both methods to evaluate the relative repeatabilities of the methods. The differences between check determinations averaged, for all samples, slightly less than 5 per cent for the salt method and about 9 per cent for A.S.T.M. Method D 663.

As regards reproducibility, results obtained by different operators using the salt method showed differences averaging 15 to 20 per cent, each operator titrating in accordance with his own interpretation of a brief outline of the method.

Results obtained by different operators using A.S.T.M. Method D 663 did not represent a fair picture of the reproducibility of the method. The results by the three operators amounted to three sets of results by different methods.[5]

The results that were already available had been obtained by Method D 663–42 T,[4] following a technique adopted by an expert analytical chemist after extensive study of the method and consultation with other laboratories. This technique was within but more restricted than required by the method. The two sets of check determinations on the same samples were run by the method as revised in 1944 (D 663–44 T) rather than by 42 T, since it was desired to use the method in its current form and it was not expected that the slight changes involved (44 T *versus* 42 T) would significantly affect the results. One operator interpreted the D 663–44 T method to prescribe shaking vigorously toward the end of the titration—actually putting a stopper in the flask and shaking up and down. This operator also took advantage of the 3-min. titration time allowed for special cases. The other operator ran the titration according to the way certain critical parts of the 44 T method were meant to be interpreted—not shaking but vigorously swirling the flask in the final stages of the titration and completing the titration in not less than 60 sec. and in not more than 90 sec.

A comparison of the three sets of results on all fifty samples showed:

The results by the 42 T method were by far the lowest. Those obtained by the 44 T method, using swirling throughout and a 60 to 90-sec. titration time, averaged about twice as high as the 42 T results. Those obtained by the 44 T method, using vigorous shaking and the longer titration time, averaged four times as high as the 42 T results.

Summary

The advantages of the salt method compared to A.S.T.M. Method D 663, based on the above limited and miscellaneous collections of runs, are as follows:

Acidities by the salt method are of somewhat more significance in relation to bearing corrosion. Not too much importance is attached to this generalization, since any acidities are of real significance only when extensive background on the oil concerned is available.

Results are more readily duplicated by the salt method. This method would be especially preferred when the operators are frequently changed and much depends upon interpretation of a written procedure.

[5] Due to illness, none of the people with any detailed experience with A.S.T.M. Method D 663 acidity method were available for consultation during the greater part of this work. The only directions for procedure were those in the Book of A.S.T.M. Standards on Petroleum Products and Lubricants (D-2 compilation of standards), which should have sufficed. Even though the three series of results are not what was originally planned, they are discussed to show the sensitivity of the method to slight variations in technique.

Reprints of this complete Symposium on Neutralization Number will be available.

Electrical Conductivity of Conductors

By L. F. Roehmann[1]

SYNOPSIS

The multiplicity of terms and units employed to designate the electrical resistivity and conductivity of conductors has led to inconsistency and confusion. Specifically, the creation and codification of mass resistivity and mass conductivity, on a par with volume resistivity and volume conductivity, seem unnecessary and confusing. It is therefore suggested, in dealing with electrical conductors, to retain but one quantity, and to use it universally. For this quantity, per cent volume conductivity is suggested. The reasons for this choice are given.

With present-day measuring technique, per cent volume conductivity can always be determined with a sufficiently high degree of accuracy, even if area has to be determined indirectly from length, weight, and density. The validity of this statement is supported by test data on fine copper wire, No. 36 A.w.g. (0.005 in. in diameter), bare *versus* tinned *versus* lead-alloy coated.

The following recommendations are put forward:

1. Uniformly standardize conductivity of electrical conductors on the basis of per cent volume conductivity.
2. Adopt the coil form method outlined in this paper as a tentative standard for the determination of per cent volume conductivity of fine wire.
3. Enlarge the scope of A.S.T.M. Tentative Method of Test for Density of Fine Wire and Ribbon for Electronic Devices (B 180–43 T),[2] by the inclusion of other than heavy test liquids.

AN ELECTRICAL conductor, within the scope of this paper, is defined as a metallic wire, cable, rod, bar, strip, tube, or profile which is longitudinally invariant. This means that the cross-sectional area is constant, and, in addition, that the cross-sectional metal distribution does not change if the conductor is made of different metals. Examples are Copperweld wire (steel core with copper sheath) and fine copper wire with tin or lead-alloy coating.

VOLUME AND WEIGHT RESISTIVITY

The interrelation between resistance R, length l, and area A of an electrical conductor is expressed by the well-known equation

$$R = \rho \frac{l}{A} \quad \ldots\ldots\ldots\ldots (1)$$

where the proportionality factor ρ is termed the resistivity or, more accurately, volume resistivity. The resistance R is the quantity which enters directly into voltage and current calculations of a specific circuit. It depends upon the length of the conductor and its cross-sectional area. The volume resistivity ρ is not dependent upon length and area. It is a more fundamental quantity, and usually associated with the material of which the conductor is made.

Resistance is universally expressed in ohms. Conductor length, however, is expressed in centimeters, meters, kilometers, feet, or miles. Conductor cross-sectional area is expressed in square millimeters, square centimeters, square inches, or circular mils. It follows that the fundamental quantity, resistivity, is expressed in a multiplicity of ways, and obscured by numerous conversion factors. The same is true of volume conductivity, the reciprocal of volume resistivity, which is used by some authors in lieu of volume resistivity.

The foregoing represents but a part of the story. As an alternate to Eq. 1, and on a par with it, the following relation holds between resistance R, length l, and weight W of a conductor:

$$R = \delta \frac{l^2}{W} \quad \ldots\ldots\ldots\ldots (2)$$

According to this equation, the resistance is proportional to the square of the length, inversely proportional to the weight, and proportional to the "weight resistivity" δ. The latter is frequently misnamed "mass resistivity." The resistance is expressed in ohms; conductor length in centimeters, meters, kilometers, feet, or miles. The conductor weight is expressed in grams, kilograms, or pounds. Hence there exists a second set of resistivities, namely, "weight resistivities" and their reciprocals, "weight conductivities."

PER CENT CONDUCTIVITY

To complete the story, conductivity of a conductor, or conductor material, is customarily expressed not as an absolute quantity but as a relative quantity, namely as a percentage of a standardized conductivity. The International Electrotechnical Commission in 1913 adopted a resistivity value known as the International Annealed Copper Standard (IACS). The normal values for standard annealed copper were established as follows:[3]

"1. At a temperature of 20 C. the resistance of a wire of standard annealed copper 1 meter in length and of a uniform section of 1 sq. mm. is $^1/_{58}$ ohm = 0.017241 ... ohm.

"2. At a temperature of 20 C. the density of standard annealed copper is 8.89 g. per cu. cm.

"3. .....

"4. As a consequence, it follows from (1) and (2) that at a temperature of 20 C. the resistance of a wire of standard annealed copper of uniform section 1 meter in length and weighing 1 g. is ($^1/_{58}$) $\times 8.89$ = 0.15328 ... ohm."

From the foregoing definitions, two resistivities for standard annealed copper at 20 C. are obtained:

Volume resistivity

$$\rho_s = 0.017241 \frac{\text{ohm sq. mm.}}{\text{meter}} = 1.7241 \frac{\text{microhm sq. cm.}}{\text{cm.}}$$

or michron.-cm.

Weight resistivity

$$\delta_s = 0.15328 \frac{\text{ohm}}{\text{meter}} \times \frac{\text{gram}}{\text{meter}} = 875.20 \frac{\text{ohm}}{\text{mile}} \times \frac{\text{pounds}}{\text{mile}}$$

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 260 S. Broad St., Philadelphia 2, Pa.

[1] Research Engineer, Electrical Lab., Anaconda Wire and Cable Co., Hastings-on-Hudson, N. Y.

[2] 1944 Book of A.S.T.M. Standards, Part I, p. 1803.

[3] Circular No. 31 of the National Bureau of Standards.

Since Eqs. 1 and 2 express the volume resistivity and weight resistivity, respectively, of any electrical conductor, it follows that there are two values of per cent conductivity for any conductor:

1. *Volume* per cent conductivity

$$c = 100 \frac{\rho_s}{\rho}$$

$$= 100 \times \frac{0.017241}{\rho} \text{ (basis: ohm, sq. mm., meter)}$$

$$= 10^{-4} \times \frac{1.7241}{\rho} \text{ (basis: ohm, cm.)}$$

2. *Weight* per cent conductivity

$$c_w = 100 \frac{\delta_s}{\delta}$$

$$= 100 \times \frac{0.15328}{\delta} \text{ (basis: ohm, meter, gram)}$$

$$= 100 \times \frac{875.20}{\delta} \text{ (basis: ohm, mile, pound)}$$

Volume per cent conductivity and weight per cent conductivity are numerically equal only if the conductor density at 20 C. is 8.89, that is, if the conductor is made of copper. For other values of density, the two conductivities are numerically different.

To recapitulate, the electrical resistivity, or conductivity of an electrical conductor can be designated by the following quantities:

Volume resistivity or Volume conductivity	Expressed in numerous ways, depending upon the units used for measuring length and area.
Weight resistivity or Weight conductivity	Expressed in numerous ways, depending upon the units used for measuring length and weight.
Per cent volume conductivity or Per cent weight conductivity	Expressed in per cent of IACS.

The complications which ensue from this multiplicity of terms, definitions, and units are well reflected in Table I. This is a compilation prepared from A.S.T.M. specifications pertaining to electrical conductors, and shows the wide range of expressions included for representing a single concept.

Suggested Simplification:

The need for simplification, unification, and correction is apparent. It is, therefore, suggested, in dealing with the conductivity of electrical conductors, to eliminate all quantities except one, and to use this one quantity for all conductors regardless of size, metal, or metal composition, and specific application. Per cent volume conductivity is suggested.

Per cent is suggested because this dimensionless unit is universally understandable. The reference value is 100 per cent, IACS, although it is recognized that this standard is no absolute quantity in a physical sense. Commercial copper is available today with per cent conductivities above or below 100 per cent IACS.

Volume conductivity is suggested for several reasons. First, this quantity is used exclusively, though maybe unknowingly, in verbal discussions. One speaks of an aluminum conductor of some 60 per cent conductivity, but not of one having some 200 per cent (the latter would be per cent weight conductivity). Second, commercial conductors, such as Copperweld, Copperweld-Copper composite, aluminum cables-steel reinforced (ACSR), or bronze, are customarily listed with actual and "equivalent copper" cross-sectional areas.[4] The volume concept is again apparent. The ratio of equivalent copper cross-section to actual cross-section is one one-hundredth of the per cent volume conductivity.

When an engineer deals with electrical conductors, he prefers, quite generally, the volume to the weight concept. Whether it is the current density, depth of penetration or even conductor resistance, it is the volume or area, not the weight concept, which he actually applies. No textbook on circuit theory or energy transmission considers weight. Field equations are a matter of potentials and geometry but not of weight. But when resistivity and conductivity are considered, both volume and weight concept are legalized, and when wire, particularly fine wire is the object, the weight concept is considered superior.

Basis for Acceptance of Weight Concept:

An important reason for the acceptance of the weight concept and its subsequent codification in many A.S.T.M. standards may have been the arguments set forth in Bureau of Standards Circular No. 31.[3] The following statements are quoted from it (page 63):

"The reasons why the mass resistivity is preferable to the volume resistivity may be summarized as follows:

"1. The measurement of either cross-section or density in many cases is difficult and inaccurate.

"2. The direct measurement of cross-section is practically impossible for irregular shapes of cross-section.

"3. Conductors are sold by weight rather than by volume, and therefore the information of value to most users is given directly by the mass resistivity."

During the interval of more than thirty years since the publication of Circular No. 31, the conclusion reached in the last reason, that "the information of value to most users is given directly by the mass resistivity," has proved to be incorrect. The designer of a Copperweld transmission line, or the purchaser of a high-strength low-conductivity bronze trolley wire, is interested in

TABLE I.—RESISTIVITY AND CONDUCTIVITY AS GIVEN IN VARIOUS A.S.T.M. SPECIFICATIONS FOR ELECTRICAL CONDUCTORS.

A.S.T.M. Designation[a]	Title	Quantity	Basis	Unit
B 187–44 T.	Tentative Specifications for Copper Bus Bars, Rods and Shapes	Resistivity Conductivity	Weight	Ohms (meter, gram) Per cent
B 1–40.....	Standard Specifications for Hard-Drawn Copper Wire	Resistivity	Weight	Ohms (mile, pound)
B 105–39...	Standard Specifications for Hard-Drawn Copper Alloy Wires for Electrical Conductors	Resistivity	Weight Volume	Ohms (mile, pound) Ohms (mil, foot)
A 111–43...	Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Telephone and Telegraph Line Wire	Resistivity	Weight	Ohms (mile, pound)
B 82–41....	Standard Specifications for Drawn or Rolled Alloy, 80 per cent Nickel, 20 per cent Chromium for Electrical-Heating Elements	Resistivity	Volume	Ohms per circular mil foot Ohms per square mil foot Microhms per centimeter cube
B 82–44 T..	Tentative Specifications for Drawn or Rolled Alloy, 80 per cent Nickel, 20 per cent Chromium for Electrical-Heating Elements	Resistivity	Volume	Ohms per circular mil foot Ohms per square mil foot Microhms per centimeter cube
B 118–42 T.	Tentative Methods of Testing Nickel and Nickel-Alloy Wire and Ribbon for Electronic Tube Filaments	Resistivity	Volume Weight	Ohms per circular mil foot, microhm - centimeters, or ohm-milligram per 200 millimeter-feet

[a] 1944 Book of A.S.T.M. Standards, Part I.

[4] *Electrical Transmission and Distribution Reference Book*, Westinghouse Electric and Manufacturing Co., 1942, pp. 32 and 34; and similar reference books.

the equivalent copper cross-section of the material under consideration. It is the volume, not the weight concept which predominates.

The second reason is, of course, correct but predicated upon the first. If an easy and sufficiently accurate method for indirect area determination is available, both arguments lose their foundation.

Recent Standards:

Reasoning along these lines probably led to the adoption of A.S.T.M. Standard Method of Test for Resistivity of Metallic Materials (B 63 – 36).[5] This standard sets forth a method for *volume* resistivity determination with an accuracy of 1 per cent. Referring to cross-sectional area measurements, the standard specifies micrometer measurements on wire specimens or strips, if and when the mean cross-section can be obtained within 0.5 per cent. Section 5(*a*) reads in part,

> "In case the diameter of the wire or the thickness of the strip cannot be measured to give the above accuracy with the micrometer available, the cross-section shall be determined from the weight, density, and length of the specimen."

The standard proceeds to describe density measurements in water, and to point out the necessary precautions to insure accuracy.

A.S.T.M. Tentative Method of Test for Density of Fine Wire and Ribbon for Electronic Devices (B 180 – 43 T)[2] shows the way for an improvement in accuracy for specimens of low weight. If water, with a density of 1 g. per ml. is replaced by a heavy liquid, such as tetrabrom-acetylene with a density of nearly 3, the accuracy in density determination is increased about threefold. The scope of A.S.T.M. Method B 180 provides a test method for density determination of fine wire, 0.001 to 0.010 in. in diameter, and of ribbons of similar thickness, for electronic devices, with an accuracy of 0.1 per cent. To accomplish this objective, an exacting laboratory technique is required, and the detailed procedure is set forth in the standard.

When our chemical laboratory recently undertook to determine the densities of No. 36 A.w.g. copper wire, bare, tinned, and lead-alloy coated, by following the provisions of A.S.T.M. Method B 180, difficulties were encountered. The data were erratic and not reproducible. Failure was attributed to the testing liquid tetrabrom-acetylene. Its poor wetting characteristic makes it well nigh impossible to remove all traces of air clinging to the wire, even when it is boiled under vacuum. Furthermore, the lead-alloy coated wire was corroded by the liquid.

Success was achieved by substituting isopropyl ether. This liquid is chemically inert, wets easily, boils *in vacuo* at room temperature, and has a low temperature coefficient. These advantages outweigh, in our opinion, the disadvantage of low density (0.7427 g. per ml.). Additional work on this subject is underway. It seems advisable to enlarge the scope of Method B 180 beyond fine wire and ribbon for electronic devices, and to amend the standard according to these findings.

Once density of the specimen is determined, the remaining three quantities necessary for per cent volume conductivity determinations, namely, resistance, length, and weight, are obtained quite easily.

Anaconda Coil Form Method

The Anaconda Laboratories have developed a method for tests on fine wire which is convenient and sufficiently accurate for engineering purposes. Its main feature is the use of a cylindrical coil form having a helical groove (Corning Pyrex Glass Multiform Coil Form) on which the specimen is wound. The wire specimen is soldered to rectangular copper lugs which are brazed to substantial binding posts. The assembly is inserted into a chamber with controlled heat and refrigeration to attain reference temperature. The resistance of the wire specimen is measured with an accurate Wheatstone bridge connected to the specimen by short, heavy leads. The wire is then cut off at the lugs, removed from the coil form and weighed.

Two coil forms are used. The smaller form is $3\frac{1}{2}$ in. long and has an over-all diameter of 2 in. It is used for wire sizes No. 28 to 36 A.w.g. and accommodates about 16 ft. The larger form is $5\frac{3}{4}$ in. long and has an over-all diameter of $2\frac{3}{4}$ in. It is used for wire sizes No. 22 to 27 A.w.g. and No. 37 to 44 A.w.g. and accommodates about 60 ft.

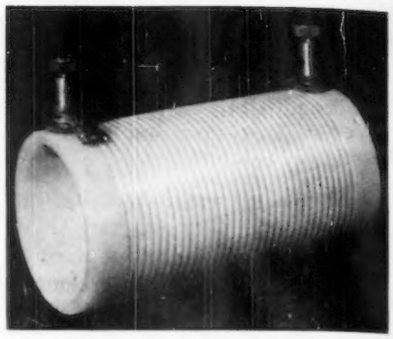


Fig. 1.—Small Coil Form with No. 36 A.w.g. Wire.

The resistance of wire sizes No. 21 A.w.g. and larger may be measured with a Kelvin bridge on straight specimens without resorting to the coil-form method.

Figure 1 shows the small coil form with No. 36 A.w.g. wire wound upon it.

The following considerations governed the development of the coil-form method and the assignment of wire sizes and lengths applicable to each form:

1. The resistance of the specimen should exceed one ohm, the lower limit for Wheatstone bridge measurements.
2. The specimen weight should exceed 0.5 g., the lower limit for accurate weighing.
3. Soldering of the wire specimens to the copper lugs eliminates difficulties due to contact resistance.
4. Dimensional stability of the coil form obviates the need for individual length measurements. The lengths between lug tips have been established for every wire size tested.
5. Compactness of the coil permits of its insertion into a small chamber and assures uniform temperature.

Application of Method:

Table II shows the results obtained in the determination of per cent volume conductivity on No. 36 A.w.g. copper wire, bare, lead-alloy coated and tinned. The simple working formulas are included in the Appendix.

[5] 1944 Book of A.S.T.M. Standards, Part I, p. 890.

TABLE II.—PER CENT VOLUME CONDUCTIVITY. NO. 36 A.W.G. COPPER WIRE, BARE, LEAD-ALLOY COATED, AND TINNED.

Specimen	Resistance, R_{20}, ohms	Length, l, cm.	Weight, W, g.	Density, D, g. per cu. cm.	Diameter, d, mils	Volume Conductivity c, per cent
Spool I						
Bare copper wire	6.870	515.3	0.5967	8.90	5.07	99.4
	6.901	515.3	0.5937	8.90	5.05	99.5
	6.860	515.3	0.5972	8.90	5.07	99.5
Same wire, lead-alloy coated	6.867	515.3	0.6341	8.97	5.20	94.3
	6.870	515.3	0.6241	8.97	5.16	95.8
Spool II						
Bare copper wire	6.874	515.3	0.5896	8.90	5.04	100.6
	6.881	515.3	0.5900	8.90	5.04	100.4
Same wire, tinned	7.032	515.3	0.5872	8.89	5.03	98.6
	7.030	515.3	0.5872	8.89	5.03	98.6
Same wire, tin removed	7.176	515.3	0.5653	8.90	4.93	100.5
	7.205	515.3	0.5630	8.90	4.92	100.5

Accuracy of Method:

These data give some idea of the accuracy to be expected. The per cent volume conductivities are consistent within ±0.1 per cent. The first three values of c, for instance, are 99.4, 99.5, and 99.5, although the resistance varies by 3 and 4 in 690. These resistance variations are offset by corresponding weight variations, as it should be.

Reproducibility:

Reproducibility is exhibited by the values from spool II. Tinning increases the resistance. Part of the tin diffuses into the copper and forms a low-conductivity bronze cylinder around a reduced copper core. Also, the tinning operation affects the diameter; the "dead-soft" copper wire is stretched so that the diameter of the tinned wire is slightly less than that of the bare wire. Due to the tinning, the per cent volume conductivity of the wire is decreased from 100.5 per cent (average) to 98.6 per cent. However, when the tin and bronze are removed by acid treatment, the original conductivity is restored although the resistance of the specimen is much higher, and the diameter is much smaller than originally.

Recommendations

The following recommendations are offered as a result of this study.

1. Uniformly standardize the conductivity criterion for electrical conductors on the basis of per cent volume conductivity.
2. Adopt the coil-form method as a tentative standard for the determination of per cent volume conductivity of fine wire.
3. Enlarge the scope of A.S.T.M. Method B 180 beyond fine wire and ribbon for electronic devices, and revise it by including other than heavy liquids.

Acknowledgments:

The author gratefully acknowledges the valuable assistance and advice received from E. W. Greenfield, Engineer in Charge, Electrical Laboratory, and from C. J. Snyder, Engineer in Charge, Metallurgical Laboratory, Anaconda Wire and Cable Co. He is particularly indebted to C. F. Carrier, in Charge of the Chemical Laboratory, who personally made the density determinations, and who suggested and used isopropyl ether as a testing liquid.

APPENDIX

List of Symbols

Symbol	Quantity	Unit
A	Cross-sectional area	sq. cm.
c	Per cent volume conductivity	per cent
d	Wire diameter	mils
D	Density	g. per cu. cm.
l	Length	cm. or ft.
R	D-C resistance	ohms
W	Weight	grams
ρ	Volume resistivity	ohm-cm.
ρ_s	Volume resistivity of IACS at 20 C.	ohm-cm.

Formulas

I. *General Case.*—Per cent volume conductivity for any cross-sectional area A, in square centimeters, and length l, in centimeters.

$$\rho = \frac{RA}{l} \text{ ohm-cm.}$$

$$\rho_s = 1.7241 \times 10^{-6} \text{ ohm-cm.}$$

$$\therefore c = 100\,\frac{\rho_s}{\rho} = \frac{1.7241 \times 10^{-4} \times l}{RA} \left(\frac{\text{cm.}}{\text{ohm, sq. cm.}}\right)$$

where $A = \frac{W}{lD}$ sq. cm.

II. *Special Case.*—Per cent volume conductivity of round wire with diameter d, in mils, and length l, in centimeters or in feet.

$$c = 34.02\,\frac{l}{Rd^2}\left(\frac{\text{cm.}}{\text{ohm, sq. mils}}\right)$$

or

$$c = 1037\,\frac{l}{Rd^2}\left(\frac{\text{ft.}}{\text{ohm, sq. mils}}\right)$$

Bureau of Standards Indices

The latest Supplementary Index List of the National Bureau of Standards covers the period from January 1, 1942, through June 30, 1944, and is one of four such indices which together afford a complete list of published items from the establishment of the Bureau in 1901. Each of the four lists gives general information on how to purchase publications, a list of depository libraries, series numbers, titles, and abstracts of publications. A major portion of each list involves abstracts of the research papers. Each list has a complete subject and author index. Almost any engineering technologist, particularly if he is concerned with materials and their tests and applications, would find these lists of service. Copies can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. as follows:

Circular No. 24—1901–1925, 271 pp.—25 cents
Supplement—1925–1931, 214 pp.—25 cents
Supplement—1932–1941, 386 pp.—50 cents
Supplement—1942–1944, 84 pp.—20 cents

Reprint on Electrical Contact Sizes

Reprints have been struck off of the material published in the December Bulletin providing standard dimensions for projection welding contacts and for contact rivets. The committee in charge, a subgroup of Committee B-4 on Electrical Resistance Alloys, has procured a large number of these reprints and copies can be obtained from the organizations represented, or members may obtain one without charge by writing A.S.T.M. Headquarters. This material was published on pages 37 and 38 of the December Bulletin.

Discussion of Paper on

A New Machine for Measuring Wear Resistance of Walkway Materials[1]

Submitted by J. R. Shank:[2]

It appears that the authors have developed a testing procedure that meets demands very well for walkway materials, particularly when the materials to be tested are similar in hardness to those described. It does not seem to be so well adapted to materials of the brittle, hard, heavy, earthy, granular types such as stones and cement products. The writer had some experience in trying to adapt the Dorry testing machine to this service for the hard materials. As a result of this experience he is of the opinion that the authors' basic factor, "(*a*) The surface against which the test material moves should be steel," does not well suit the testing of hard, walkway materials. The tests which the writer reported upon[3] were more indicative of the resistance of the material to the action of a jumper drill than to ordinary walkway abrasion. The addition of a rubber pad between the steel disk and the specimen gave results which were very different from those reported and which seemed to fall better in line with experience with marbles.

Inasmuch as the abrasive action on walkways is brought about through the action of rubber or leather shoe soles, it appears that any testing apparatus for resistance to abrasion must have a cushion somewhere between the test specimen and the platen carrying the abrasive. The authors have this cushion, in the cases of all three materials tested, in the materials themselves. Had they been testing marble this would not have been the case.

If the specimen and the platen are both hard and have large mass or inertia values, in comparison with the abrasive particle, the action of the particle is to drill into one or the other, or both, with every turnover of the more or less irregular particle. If the face of one or the other materials in contact with the abrasive particle is of such a nature as to allow the particle to penetrate it without drilling a piece out of it, then the action is more nearly like the action of a shoe sole with sand on it. A difficulty that arises then is that of accelerating the test and keeping down the cost of platen material sufficiently to make the test procedure practical.

The dropping of the specimen $\frac{1}{16}$ inch hardly seems important inasmuch as the impact of shoe soles on walkways is never great and is absorbed by the material of the sole, particularly when it is rubber or like rubber in its texture. If, however, the walkway is to be subjected to steel tired wheels or sliding metal shoes and is of a hard material, the factors (*a*) and (*b*) are both important and the Dorry test is well suited.

[1] A. W. Cizek, Jr., D. H. Kallas, and H. Nestlen, "A New Machine for Measuring Wear Resistance of Walkway Materials," ASTM BULLETIN No. 132, January, 1945, p. 25.

[2] Assistant Director, Engineering Experiment Station, The Ohio State University, Columbus, Ohio.

[3] "A Wear Test for Flooring Materials." J. R. Shank, Vol. 35, Part II, *Proceedings*, Am. Soc. Testing Mats., p. 533 (1935).

What Standardization Means to the Navy[1]

By Rear Admiral E. L. Cochrane, Chief, Bureau of Ships, U. S. Navy

EDITOR'S NOTE.—The subject matter of this address and the very active interest of the U. S. Navy in A.S.T.M. made it appropriate to excerpt the material in the BULLETIN. In the January, 1943 BULLETIN was published a short talk by Commander E. C. Forsythe, then Officer in Charge, Standards and Test Section, Bureau of Ships, on the subject of specifications, and in the March, 1934 BULLETIN was the address presented at the A.S.T.M. Spring Meeting in Washington by then Captain, now Rear Admiral, C. A. Jones on the subject "Some Phases of the Relationship Between the U. S. Navy and Industry."

SO FAR as the Navy is concerned, there never has been any doubt concerning the prime necessity for standards. In the early days it was necessary that certain standard equipment should be utilized in the outfitting of all types of ships. I refer to such things as the dimensions and strength of cordage, the quality of sailcloth, the weight and dimensions of round shot, anchors, blocks, and the details of gun carriages—to mention only a few. It should not for a moment be supposed that these standards were not good standards because they were not the product of extensive scientific and engineering research. They were developed over a long period of years in the hard school of practical experience. These standards sufficed for a good many years—in fact, up to the time of the introduction of steam and the adoption of iron as the basic material of ship construction.

It was not until nearly a generation after the Civil War that any marked development was undertaken in the field of standardization in the Navy. Actually it was about 1880, with the commencement of the construction of the "White Squadron," that real progress began to be made on what has since proved to be the foundation of our present series of standards.

FEDERAL SPECIFICATIONS BASED ON EARLIER STANDARDS

During the period from the end of the Spanish-American War until the entry of the United States into World War I, gigantic strides were taken in the development of the nation's most important industrial enterprises. Paralleling this development, the United States Navy, particularly under the leadership of Theodore Roosevelt, experienced a tremendous expansion, all of which was predicated upon what were then considered to be rather complete and—if I may be pardoned for the use of the expression—"pretty good" specifications for a wide variety of materials. As you well know, it was against the background of these specifications that the Federal Specifications were developed in the years immediately following the First World War.

Throughout the greater part of the past twenty years, I have been closely associated with the designing of American men-of-war. I speak with the deepest conviction when I say that nothing of what has been accomplished would have been possible without *dimensional* standards and without *quality* standards.

On the other hand, had we accepted too broad a standardization, had we permitted standardization to crystallize our early materials or early designs before they were ready to be frozen, again little that has been accomplished would have been possible.

Today, the designer of a Naval vessel enjoys complete freedom—so far at least

[1] Excerpted from January, 1945, *Industrial Standardization;* presented at the December, 1944, Annual Meeting of the American Standards Association.

as standards are concerned—in the selection of forms and methods in which to employ steel and other materials of the required quality guaranteed by the anchor mark of our Naval inspection. From the standpoint of the designer, these are, indeed, excellent standards.

Perhaps more forcibly than any other single development of the war, the importance of standards has been brought home to us in connection with the problem of keeping our ships in every quarter of the globe adequately supplied with what the Navy originally—and to my way of thinking, unfortunately—elected to call "spare parts," and which we are now referring to as "repair parts." Here, again, exact dimensional standards and quality standards are absolutely indispensable. I speak with great feeling on this point because today my Bureau is faced with the almost overwhelming task of supplying repair parts for the nearly 100,000,000 shaft horsepower of steam, Diesel, and gasoline engines which are propelling the ships of the United States Navy all over the world today—not to mention parts for thousands of other items of equipment. This represents the most complex procurement problem with which we have yet been confronted. It requires standardization of materials of requisite quality, standardization of manufacture to exact tolerances, standards of marking, standards of packing to assure that the material will remain in suitable condition for use despite storage for months on end under the trying conditions of the tropics, standards of storekeeping, issue, installation and operation, standards of acceptability, wear and tear, and return for salvage of used parts, standard methods for reporting usages and expenditures and for translating these reports into further procurement adequate to maintain the necessary flow of replacements. Hundreds of millions of dollars are being expended on this effort and I am happy to be able to say that so far, at least we have been able to meet the needs of our ships so that they have not been forced to drop out of the battle line for any lack of repair parts. We have, however, in this respect been running on a slender thread of security, and the success of the effort to date could not possibly have been achieved without standardization, spelled with a capital "S."

Too Early Standardization

On the other hand, there have been times when the push and pressure of the war effort have forced us into the standardization of ship designs for purposes of quantitative production before they had achieved that highly desirable characteristic of becoming *proved* designs. In every case we took a "calculated risk" that the design would prove to be satisfactory, and in every case standardization on that design has proved to be the key to successful mass production.

At no time has standardization been permitted to stand in the way of design improvements to increase the striking power of our arms or to strengthen their resistance to the offensive power of the enemy. Take, for example, the destroyer. Since 1932, when after the shipbuilding doldrums of the 'twenties, we again undertook the development of the type, we have had seven or eight different destroyer designs, each superior to its predecessor, so that the destroyers which are coming off the ways today—and I say this without the slightest fear of contradiction—are the finest destroyers that have ever been launched by any Navy in the world. Still we are not fully satisfied, and even today we are going forward with the design of an even better destroyer—one which will be able to go with the larger battleships and carrier types which are now being added to our Navy or which we now have in prospect. This is the only way that we can hope to keep the United States Navy in the position of world dominance which it so definitely occupies today.

It is of the utmost importance that standardization shall be made a tool of progress for the United States, not only in maintaining the strength of its military and naval arm, but also in supporting its commercial relationships with the rest of the nations of the world in the postwar period.

Heretofore it has been possible for us to busy ourselves almost exclusively with competition with each other within the boundaries of the United States. For this internal trade, nation-wide standardization has been of the greatest importance.

But when the war is over, and the United States emerges from it as the leading nation of the world, it will be necessary for us in maintaining that position to seek markets for our products elsewhere in the world and beyond our own boundaries.

I am convinced that some standardization of quality for the products of United States manufacture intended for purposes of export in the postwar period will be absolutely essential. I do not mean to say that we should not produce goods of various qualities within varying price ranges in order to meet the demands of markets where sufficient wealth is lacking for the purchase of high-quality goods. But some standardization of markings seems to me to be strongly indicated in order to show what quality of goods is, in fact, being sold and to protect high-quality markets from being flooded and ruined with goods of inferior quality designed for the poorer markets.

There will be many such problems to be solved in connection with the tremendous scientific and engineering advances which are certain to come in the years immediately following the termination of present hostilities. These advances will present an opportunity for progress in the field of standardization beyond anything we have previously experienced.

We hope that the Navy will be permitted to share in these technological advances and developments of the future. Unless it *is* permitted to keep abreast of them, it will be exceedingly difficult for the Navy to retain its present position of supremacy.

It is a benighted man, indeed, who would suppose that because we have built a Navy which *today* can stand up and hold its own against any possible antagonist, we can keep that dominating position by simply sitting tight and holding on to what we now have. If you want to coast, you can go in only one direction—and that is downhill.

I hope, therefore, that we can all look forward to a continuance for many years of the close teamwork which has been built up between the Navy and this Association. Together this partnership has achieved some fine results. Together it can achieve still greater ones in the years to come.

RBNS

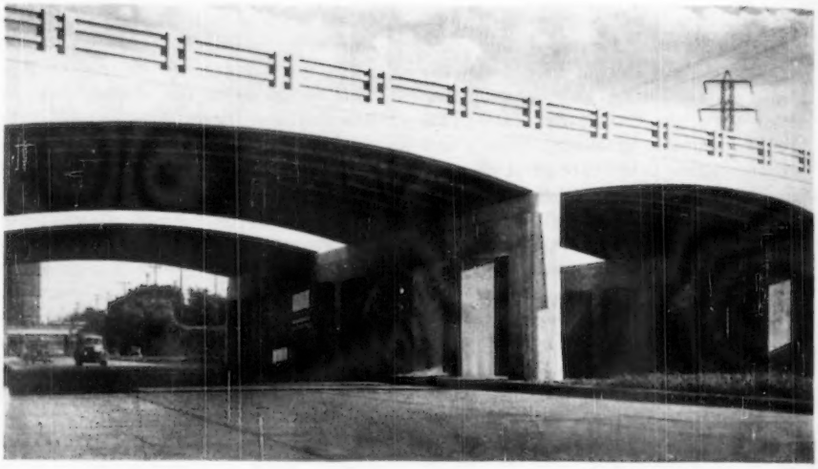
The Research Board for National Security, requested by the Secretaries of War and the Navy and recently established by the National Academy of Sciences, is to be the peacetime successor to the Office of Scientific Research and Development, pending possible ultimate authorization of an independent research agency by Congress. The new Board will formulate programs of research on national security and will conduct research under contracts whereby existing laboratories and facilities are used wherever possible.

The war has proved the need of the Armed Services for the far-sighted contribution of scientific research, and the need of the scientist for a working familiarity with military personnel, procedures and problems, according to the announcement of the Board's formation. For this reason, the membership of the Research Board for National Security includes twenty civilian scientists and twenty high-ranking Army and Navy officers. Karl T. Compton, President of the Massachusetts Institute of Technology, is chairman of the Executive Committee.—*Research Bulletin of Arthur D. Little.*.

"Well" between structures of Detroit Industrial Expressway over Greenfield Rd., looking east.

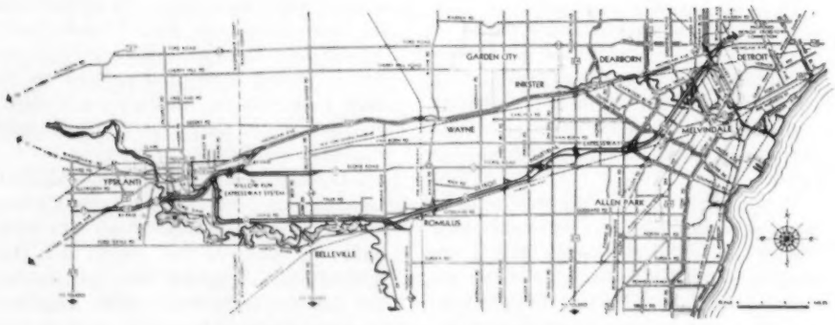
Greenfield Rd. looking south under Detroit Industrial Expressway.

Extensive Use of A.S.T.M. Specifications in New Willow Run-Detroit Expressway



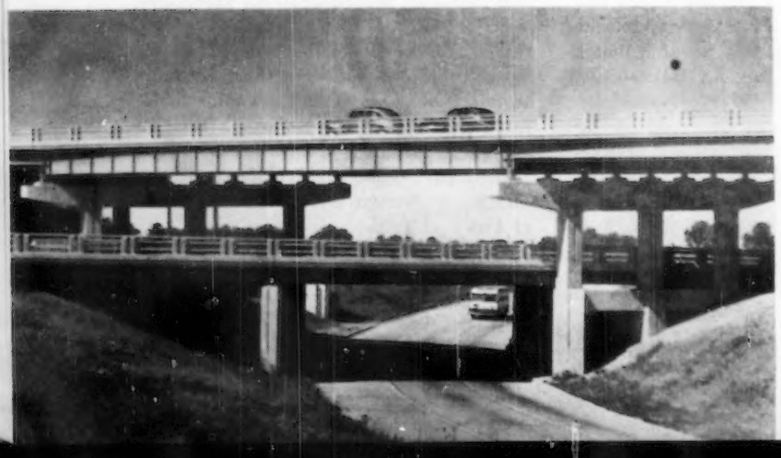
THE accompanying map and illustrations show the extent of the Willow Run-Detroit Expressway System, which was dedicated on March 9. It speeds workmen from the Detroit area to the huge Ford Bomber plant, 27 miles from downtown Detroit. Its wartime job has been to provide a most important link from the city to the bomber plant. After the war, the expressway will offer a speedy entrance and exit to the Detroit area for highways west and south of the metropolis. It will have excellent connections to Chicago and highways in Ohio, Illinois, and Indiana as well as southern and southwestern Michigan.

Carried out by the Michigan State Highway Department, of which C. M. Ziegler is Commissioner, the expressway is another of the extensive projects where A.S.T.M. specifications and tests have had an important part. In requesting information from R. F. Swan, Public Relations Dept., and W. W. McLaughlin, Testing and Research Engineer, member of A.S.T.M., we received a copy of the Michigan State Standard Specifications for Road and Bridge Construction, which generally covered this extensive new project. This book reveals a large number of references to A.S.T.M. specifications.



Map showing Willow Run and Detroit Expressway.

East Tri-level.



The Willow Run Expressway, forming a "U" around the plant, has over 21 miles of two, four, six, and eight-lane pavements, each lane 11 ft. wide. It joins the Detroit Industrial Expressway, composed of 17.1 mi. of four 12-ft. lanes of divided highway, at Hannan roads. This makes a continuous system approximately 38 miles long. Two bridges, 43 highway grade separations and 11 rail separations are included in the two expressways. Concrete pavement slabs are 9 in. thick, placed on a 2-ft. sand cushion.

The roadway is approximately 3 ft. above ground level except for the last 2 mi. on the east end of the Detroit Industrial Expressway where it became advisable to depress the highway to go under an intricate web of streets and railroads, rather than attempt to go above this cross traffic.

References to A.S.T.M. standards in the Michigan Standard Specifications for Road and Bridge Construction cover steel (structural, bridges and buildings, rails, concrete reinforcement, etc.); non-ferrous metals (copper, lead, aluminum, bronze and other alloys); constructional materials—quicklime for structural purposes, paving brick, sewer brick, concrete, cement, paint, varnish, lacquer, and other materials.

The Future of Industrial Research

REPRINTS of three of the very interesting papers and discussion presented at the Silver Anniversary Forum on the Future of Industrial Research as sponsored by the Standard Oil Development Co. in New York on October 5, 1944, have been made available and A.S.T.M. members can obtain a copy of the following items by writing to the Standard Oil Co., Room 1336, 30 Rockefeller Plaza, New York 20, N. Y.:

Industrial Research and National Defense—Robert P. Patterson, Under Secretary of War.

Summary of Silver Anniversary Forum on The Future of Industrial Research—Frank A. Howard, President, Standard Oil Development Co.

The Future of Industrial Research—Thomas Midgley, Jr., Late President and Chairman of the Board, American Chemical Society.

All of the papers and discussion presented have been published in book form. It is not feasible to abstract adequately the material presented or the three reprints that can be obtained, but selected excerpts follow:

From "Industrial Research and National Defense"

"There must be an avenue between industry, university laboratories, government laboratories, and the armed services . . . and no one-way signs.

"Repeatedly this war has shown that science leads tactics; this will be fully as true in wars of the future.

"There is no four-lane highway to scientific achievement; a bulldozer is needed every inch of the way.

". . . the future of our country in peace and in war is to a great extent in the hands of American scientists."

From "Summary of Silver Anniversary Forum on the Future of Industrial Research"

"These three—scientific research, development, and invention—are the components of technical progress in industry. It is the function of industrial research to harness the three components in a sustained common effort, and to keep the effort headed in the right direction." (Howard)

"In general, the objective of industrial research is the material objective of civilization itself—to prolong life, to improve health and comfort, to enhance happiness, and to enlarge productive ability and usefulness." (Derby)

"The primary responsibility of a research development organization to the industry with which it is associated is, of course, in the new or improved things which it brings to that industry. Wise management will see to it that those who direct its research and development organization are an integral part of its policy-making group." (Jewett)

"During the past twenty-five years industrial research has expanded ten times. In 1940, 70,000 scientists were engaged in it, and this is a rather large percentage of the total number available. Another sizable group must remain in educational work, or the whole system will collapse." (Midgley)

"Industrial research organizations seem certain, therefore, to grow in number, in size and in diversity of fields covered, and to play an increasingly dominant part in determining our economic, and so, political future." (Jewett)

"No director who is any good ever really 'directs' any research. What he does is to protect the research men from the people who want to 'direct' them." (C. E. K. Mees)

"There are certain types of research which must be carried on with government financing and government help. But it should stop with those things which are purely for war or national defense, and let the private initiative and business competitive system carry as much of the load as possible." (Dewey)

"In the next world war, which will inevitably come some day, but we hope not in our lifetime, the 'lightning war' will be much more feasible because of the rapid development that is taking place, that cannot be stopped, and that will be world-wide. The only safeguard against it by a free and peaceful people, such as ourselves, is to be so far ahead in our progress that no nation will take the risk of attacking us." (R. E. Gillmor)

From "The Future of Industrial Research"

". . . there is no longer any reason why the smaller units of industry should not make full use of industrial research for their own advancement and welfare.

"Unless the public cooperates and raises its living standards as rapidly as industrial research makes it possible, unemployment is the inevitable result.

". . . accelerating expansion of potential fundamental knowledge constitutes an ever-growing stockpile of raw material ready for fabrication by industrial research."

Welding Foundation Textbook Award

THE James F. Lincoln Arc Welding Foundation, Cleveland, has announced another award program, this one to encourage the preparation and publication of textbooks, one on machine design and another on structural design for fabrication by all processes, including welding. A Committee on Rules, comprising leading Deans of Engineering from various schools, has been appointed, and in each class three awards are set up of $5000, $3000, and $2000, respectively. Full details can be obtained from the Foundation, Cleveland 1, Ohio.

South lane Detroit Industrial Expressway crossing Ecorse Rd. looking east.

Advances in Plastics

In his extensive article published in *Modern Plastics* and in *Mechanical Engineering* and abstracted in the February Technical News Bulletin of the National Bureau of Standards, Dr. Gordon M. Kline cites 1944 as a year marked by the growth of technical literature on properties and testing of plastics with almost double the number of articles over the previous year.

Technically, according to Dr. Kline, the highlight of the year was the Symposium on Plastics held under the auspices of the American Society for Testing Materials in Philadelphia in February. Among the subjects covered were the heat resistance of laminates, effect of environmental conditions on the mechanical properties of plastics, diffusion of water through plastics, stiffness and brittleness of vinyl elastomers, behavior of plastics under repeated stress, testing of high-strength plastics, and creep characteristics of plastics.

The formation of A.S.T.M. Committee D-14 on adhesives was announced during the year. Subcommittees on strength properties, analytical tests, permanence properties, working qualities, specifications, and nomenclature have been organized. The cooperative efforts of producers, users, and other interested groups in the activities of this committee should lead to uniform testing procedures and valuable data on the properties of all types of adhesives, and promote the development of improved resinous bonding materials.

Dr. Kline points out that the total production of synthetic resins during 1943 was a record figure of 650,000,000 lb., a tenfold increase over that of a decade ago. New high temperature silicone resins have provided the basis for the greatest advance in electrical insulation since the advent of glass fiber. He refers to the advantages of sandwich construction involving stiff, dense faces separated and stabilized by a thick, light core. In the aircraft industry considerable interest has been stimulated in sandwich materials by the ever-increasing difficulty of maintaining rigid contours in high-speed aircraft.

Advances in high-frequency preheating equipment and the use of heatronic molding have resulted in amazing reductions in curing time. For example, curing time of a propeller block has been reduced from 12 to 2 min.; telephone handset, 8 to 3 min.

The year 1944 was a notable one for a steady growth of familiar products rather than radically new ones and this same situation existed with respect to plastics in the war effort, although one outstanding new use was the rocket launching tube which is about 10 ft. long with an inside diameter of $4^1/_2$ in. frequently mounted in clusters on fighter planes.

Damping Capacity—A General Survey of Existing Information

This report has been prepared by Prof. F. C. Thompson of the University of Manchester for the British Non-Ferrous Metals Research Association. The publication, available from the Association Headquarters, Euston Street, London, N.W. 1, at three shillings and sixpence, comprises a survey of the present knowledge of the fundamentals of damping capacity such as its metallurgical and mechanical significance and the validity of present methods of determining it. Suggestions are made of directions in which future experimental work might prove fruitful. The survey was prepared to guide the B.N.F.M.R.A. Main Research Committee in considering the desirability of initiating research on the subject. No attempt has been made in it to produce a compilation of numerical data. There is a bibliography of 58 references supplementing existing bibliographies to which reference is made.

Index of Equivalent Specifications

A new edition of the "Cross-Index of Chemically Equivalent Specifications and Identification Code" has been prepared by the General Motors Corporation at the request of the Armed Services. Dated March 1, this publication was first issued about two years ago. A large number of government agency and engineering society specifications are covered, with over 100 pages devoted to chemical analysis of the materials covered, and a specification-cross index with some 70 pages. The section on A.S.T.M. specifications is an extensive portion of this part of the book.

Copies of the index can be obtained from the Office of C. L. McCuen, Vice-President in Charge of Engineering. Requests should be directed to R. L. McWilliams, 8-135 General Motors Building, Detroit 2, Michigan. In writing it is suggested that members and others mention the ASTM Bulletin.

Spectrochemical Symposium

The February Analytical Edition of *Industrial and Engineering Chemistry* includes the first few of several papers comprising a Symposium on Spectrochemical Methods of Analysis held during the American Chemical Society meeting in New York in September, 1944. Because of time limitations, many instrumental developments could not be covered but the discussions did concern in detail analytical methods. Undoubtedly many A.S.T.M. members will be interested in these papers.

Airframe Materials

F. S. Stewart, Quality Division, Douglas Aircraft Co., Inc., has prepared a volume just issued by the McGraw-Hill Book Co., Inc., on Airframe Materials. It is designed as an introductory textbook, discussing mechanics of materials and giving in reasonably detailed fashion accounts of the processes used to assemble lightweight materials of which airframes are constructed. Described in the book are heat treatment of aluminum, welding, metal working, adhesives, sealing, plastics, synthetic resins and rubbers—all materials and processes of value to the airframe. There is no bibliography included in the book, but it is well illustrated, and there is considerable tabular material providing important data in condensed form. $5^1/_4$ by $8^1/_4$ in., 250 pages, price $2.50.

Ebulliometric Measurements

"The technique of precise determinations of boiling and condensation temperatures has recently advanced to such an extent that the special terms 'ebulliometry' and 'ebulliometric measurements' are now generally used for that kind of laboratory technique and measurements." This statement is the first paragraph of this new book from Reinhold Publishing Corp., New York, as prepared by W. Swietoslawski, Professor *in absentia* of Physical Chemistry of the Institute of Technology, Warsaw, now Senior Fellow, Mellon Institute of Industrial Research.

Ebulliometric measurements, according to the author, have found large application in ascertaining the degree of purity of liquid substances, in examining the azeotropy of binary and ternary mixtures, in molecular weight work, in microanalytical determinations of impurity contents, in studying the thermal resistivity of liquids, in tonometry, and in everyday analytical tasks. There are, of course, other fields in which the use of the method can and will be cultivated.

Chapter headings will indicate general topics covered: Measurements, Classification of Liquid Mixtures, Comparative Measurements, Calibration of Thermometers, Determination of Purity of Liquid Substances, Ebulliometers and the Study of Azeotropy, Determination of Moisture Content, Examination of Thermal Resistivity, Molecular Weight Determination, Boiling and Condensation Phenomena Under High Pressure, Examination of Physicochemical Standards, etc.

The 236-page book, documented with some 85 references and an author and subject index, page size 6 by 9 in., is available from the publishers, 330 West 42nd St. New York, N. Y., at $4 per copy.

Cooperation with A.S.M.E Boiler Code Committee

H. B. Oatley Is Committee Chairman

ONE of the groups with which A.S.T.M. through its technical committees has been cooperating very closely on questions dealing with adequate specifications for materials has been the Boiler Code Committee of The American Society of Mechanical Engineers. This committee devotes its attention to matters concerning safety in the construction of steam boilers and other pressure vessels. The Boiler Code Committee has functioned continuously for over 34 years (it was appointed by the A.S.M.E. Council in 1911) in the formulation and interpretation of the rules that comprise the A.S.M.E. Boiler Construction Code.

The present chairman of the Boiler Code Committee, Mr. H. B. Oatley, Vice-President, The Superheater Co., has been very active in A.S.T.M. work for many years and is vice-chairman of Committee A-1 on Steel. A number of the members of the Boiler Code Committee and of its numerous subcommittees are also active in the work of A.S.T.M., and this overlap in membership has served very well in tying in so closely the work of the two organizations.

The A.S.M.E. Boiler Construction Code consists of nine sections on the following subjects:

Power Boilers,
Material Specifications,
Low-Pressure Heating Boilers,
Unfired Pressure Vessels,
Boilers of Locomotives,
Miniature Boilers,
Rules for Inspection
Suggested Rules for Care of Power Boilers, and
Qualifications for Welding Procedure and Welding Operator.

Each section is published separately, and together they constitute the complete Boiler Code.

Material Specifications

In its cooperative relations with the Society the Code Committee looks to the A.S.T.M. for the preparation of detailed specifications covering materials approved for use in the construction of boilers and other pressure vessels. Matters dealing with material specifications are first considered by the Code Subcommittee on Material Specifications, the members of which are as follows:

Perry R. Cassidy, Chairman
W. P. Gerhart
W. G. Humpton
P. J. Smith
T. G. Stitt
A. C. Weigel

The largest section of the Code is the one dealing with Material Specifications. The present 1943 edition includes 68 specifications, totalling 426 pages. Including the addenda issued in 1944, 12 new specifications, comprising another 100 pages, this section involves 526 pages. All of the 80 Boiler Code specifications are identical with or substantially the same as those of the A.S.T.M. In order to assist in identifying Code specifications with the corresponding A.S.T.M. standards, the Code Committee in 1943 adopted a new system of designating the Code specifications in which the letter "S" is used as a prefix with the A.S.T.M. serial number; for example, the A.S.T.M. Specification A 70 for Steel Boiler Plate is designated as Code Specification SA-70.

The following list gives the designations of the 80 A.S.T.M. specifications included in the Code, classified according to the general nature of the materials covered:

Boiler Steel Plates and Rivets

SA-7	SA-89	SA-204
SA-18	SA-129	SA-212
SA-30	SA-201	SA-225
SA-31	SA-202	SA-266
SA-70	SA-203	

Welding Electrodes and Rods

SA-233	
SA-251	
SB-184	

Steel Castings

SA-27
SA-95
SA-157
SA-216
SA-217

Steel Tubes and Pipe

SA-53	SA-181	SA-213
SA-83	SA-182	SA-214
SA-105	SA-192	SA-226
SA-106	SA-206	SA-249
SA-135	SA-209	SA-250
SA-158	SA-210	

Steel Bolting Materials

SA-96
SA-194
SA-251

Corrosion-Resisting and Heat-Resisting Steels

SA-176
SA-240

Corrosion-Resisting Clad Steels

SA-263
SA-264
SA-265

Wrought Iron

SA-72,
SA-83
SA-84,

Cast and Malleable Iron

SA-47
SA-48
SA-197

Aluminum and Aluminum Alloys

SB-126
SB-178

Copper and Copper-Alloy Forgings, Bars, Rods, and Shapes

SB-12	SB-42	SB-98
SB-13	SB-43	

Copper and Copper-Alloy Pipe and Tubes

SB-42
SB-43
SB-111

Copper and Copper-Alloy Castings

SB-61
SB-62

Copper and Copper-Alloy Sheets, Strip, and Plate

SB-11	SB-127
SB-75	SB-171
SB-96	

Nickel and Nickel Alloys

SB-127	SB-164
SB-160	SB-165
SB-161	SB-166
SB-162	SB-167
SB-163	SB-168

The rules formulated by the Boiler Code Committee are intended to afford reasonably certain protection of life and property. The rules, of course, provide a margin for deterioration in service for the purpose of giving a reasonably long safe period of usefulness. The A.S.M.E. Code has been adopted by 25 states, the District of Columbia, the Hawaiian Islands, 17 cities throughout the country and 6 Canadian provinces. Each state and municipality that has accepted one or more sections of the Boiler Code is invited to appoint a representative to act on a Conference Committee. This Committee at present has a membership of 45.

In its work the Boiler Code Committee also cooperates very closely with the National Board of Boiler and Pressure Vessel Inspectors, which is composed of the inspectors of the states and municipalities that have adopted the A.S.M.E. Code. Since its organization in 1919, the National Board has functioned to administer uniformly and enforce the rules of the Code.

ASTM Bulletin

MAY 1945

NO. 134

TWO-SIXTY
SOUTH BROAD ST.
PHILADELPHIA 2, PENNA.

President Bates Comments . . .

EVENTS of the past few weeks have made it certain that our Society cannot hold an annual meeting of the kind which has evolved through the years and which have been found to be not only so beneficial to the Society's activities but vital to its continued development. Instead a "business meeting" of a kind will be held. Such a meeting can only be a business meeting and in no way can furnish the customary wide contacts between individuals and groups which do so much toward affording the impetus to later individual and group efforts.

Since "conventions" have become such a vital part of all technical society activities, how can their place be filled and their customary beneficial results be otherwise accomplished? The American Chemical Society is fostering meetings in "miniature." Certain of that society's sections will hold one or two-day meetings at which papers that would have been presented at the "annual meeting" by members of a section will be presented at a meeting of the section with which they are associated. Such meetings entail no inter-city travel and hence meet the ODT travel requirements.

While our District Committees have hardly developed (with one or two exceptions) to the degree that meetings of a somewhat similar nature might be held in the immediate future, nevertheless District Committees could survey the situation in their localities and it would seem almost certain that the majority of them could hold at least a one-day meeting during the coming Fall. Here the local members who would have presented papers at the annual meeting could present their work. In such groups, smaller and more intimate in nature than the annual meetings, it is likely much valuable discussion would follow. This could be presented in the Society's annual *Proceedings*.

Committee activities should be fostered as much as ever. In some committees, the conditions are such that the present is a most propitious time for considering and actively pursuing such. The several committees which are too large to hold meetings in accord with present transportation requests, could hold meetings of the subcommittee chairmen and secretaries. These could formulate plans for the year, which plans could be implemented through meetings of the subcommittees.

Papers intended for presentation at the annual meeting can be forwarded to the Society Headquarters as soon as possible. The authors of these and of future papers should bear in mind the Society's new policy regarding publishing papers—*immediate* publication after acceptance, either as a preprint (later to appear in the *Proceedings*) or in the BULLETIN. Papers are desired "now" at all times. The BULLETIN will, in each issue, list and abstract all preprints available. Members on application will be furnished copies. Please note page 38 of the March BULLETIN.

If each *individual member* during the coming year will but slightly increase his past interest in the Society, we can be assured that the year will not show any downward trend in the Society's continued expansion or output resulting from its activities. The lack of the unrestricted annual meeting will be a loss—keenly felt. But it may also have some beneficial effects. Surely, if it could arouse in all the District Committees a continuing through the year interest and activity, such as shown by the Philadelphia District Committee, the loss of the meeting could almost be considered an over-all gain.

P. H. Bates

PRESIDENT

We Are Sorry

WE REGRET the occasion for so many notices in this BULLETIN of deaths of prominent A.S.T.M. members—more such announcements at one time than we can ever recall. Men like Hanson, Harvey, Webster, deForest, Davis, and the others gave of their technical skills unstintingly to the advancement of the Society's purposes. To their organizations and companies and to their families we owe a debt of gratitude for so many jobs well done.

Yet, we are mindful of the Society as a living organization—the A.S.T.M. which these men and many hundreds have and are promoting is at an interesting stage. Very significant extensions of work on consumer standards and simulated service testing is being planned and will develop;—a permanent Headquarters building is being purchased;—the Society's administrative setup is being strengthened;—other important changes are in prospect as a result of intensive investigations by the Study Committee (some on publications were announced in the last BULLETIN).

The Society, like life itself, is attended by both joy and sorrow. Sorrow in the loss from time to time of loyal members and associates, but mitigated because these men leave behind others trained to succeed them, resulting in a steady influx of new men with their enthusiasm and stimulating ideas. This is a very healthy situation. Our older members say so.

Extensive Proceedings Ready for Mailing

AFTER considerable delay brought about by a number of factors but including as a major one the tremendous load carried by the printer in getting out the Book of A.S.T.M. Standards and the publications of other organizations, the 1944 *Proceedings* are nearing completion and should go in the mails within the next two weeks. Many of the technical papers and reports had been preprinted in advance of their presentation at the Annual Meeting, but one report includes a most extensive appendix which was not preprinted covering the Third Progress Report on the Effect of Size of Specimen on Fatigue Strength of Three Types of Steel—Prepared by H. F. Moore and D. Morkovin.

In the section devoted to technical papers, the Edgar Marburg Lecture by Harold DeWitt Smith is, of course, outstanding, covering some 50 pages and the Symposium on Analytical Colorimetry and Photometry will be of widespread interest to many of the members. This covers some 70 pages. While there are many outstanding contributions among the *Proceedings* technical papers, the following list gives those which were not preprinted and which many members will note for the first time:

Basic Requirements in the Standardization of the Salt Spray Corrosion Test—Leo J. Waldron.

Application of Fly Ash for Lean Concrete Mixes—Harry A. Frederick.

Precision Indices for Compression Tests of Companion Concrete Cylinders—S. P. Wing, Walter H. Price, and Clement T. Douglass.

Measurement of Fading Resistance of Camouflage Type Finishes by Accelerated Weathering—J. W. Iliff and L. B. Darrall.

The Interpretation of Visual Rusting Standards—W. F. Singleton.

Factors Influencing the Breaking Strength of Army and Navy Fabrics—Werner von Bergen and John C. Hintermaier.

Impact Testing of Plastics—II. Factors Which Influence the Energy Absorbed by the Specimen—David Telfair and H. K. Nason.

Flow of Thermosetting Plastics at Elevated Temperatures—John Delmonte and E. Watkins.

The Use of Selected Waters in Pulp and Paper Manufacture—Lewis B. Miller.

Treatment of Various Types of Waters for Operating Pressures Above 400 psi.—R. E. Hall.

Classification of Feedwater for Boilers Operating Between 100–400 psi.—J. A. Holmes.

In noting the appearance of *Proceedings*, it is always desirable to call attention to the extensive discussion included. This follows the respective papers and very often presents interesting additional information and data or gives a somewhat different interpretation, and not infrequently may take polite issue with some of the conclusions noted.

In addition to an extensive table of contents, the volume, of course, includes an author and detailed subject index. The *Proceedings* are considered one of the important assets of membership and over the years the volumes have presented a tremendous amount of authoritative information on the properties and tests of materials.

More New Publications Coming

IN ADDITION to the 1944 *Proceedings* described in an adjoining article, there are several other technical books under way and some special compilations of standards are virtually completed and may be ready for shipment when this BULLETIN is mailed.

Two extensive symposiums, the first on Stress-Corrosion Cracking, held jointly with the A.I.M.E. Metals Division last fall, and the second, on Magnetic Particle Testing, sponsored by the Philadelphia District Committee are progressing with the hope that the extensive volume on stress-corrosion can be issued by late July, followed by the magnetic particle testing book. A special order blank will be sent to the members which will permit them to get these two publications at the special prices to be determined. In addition to the papers, there is considerable discussion now being edited and set in type.

A Symposium on Analytical Colorimetry and Photometry to be issued later in the year as a reprint from Proceedings will comprise about 80 pages. It should be of much interest to chemists and chemical engineers.

SPECIAL COMPILATIONS OF STANDARDS

Electrical Heating and Resistance Alloys:

To bring up to date the 1942 edition of this compilation giving A.S.T.M. standards on electrical

Society-Owned Headquarters Building

THE Executive Committee has recently taken a most important step—the purchase of a property to become the permanent headquarters of the Society.

It has been known for some months that the lease on the present quarters, terminating at the close of 1945, could not be renewed, which—coupled with the urgent need for larger quarters occasioned by the growth of all services of A.S.T.M. to its members—brought the management of the Society face to face with the serious problem of locating new quarters.

A special Committee on Headquarters went vigorously to work on the problem, and after the decision had been reached to continue the headquarters in Philadelphia, an eminently suitable property, convenient to the central business district of Philadelphia, was located. Negotiations for the purchase of the building have just been completed and it will shortly be possible for the Executive Committee to give full information to the members concerning this entire headquarters project. This will be done through a special *Letter Circular to Members* to be mailed early in June.

heating alloys, thermostat metals, materials for lamps, radio tubes, etc. a supplement, dated February, 1945, has been issued giving four 1944 tentative standards, three replacing items in the book and one a new one, a test for equivalent yield stress of thermostat materials. The three replacement specifications cover chromium-nickel-iron alloy castings (B 190), drawn or rolled alloy, 80 per cent nickel, 20 per cent chromium, for electrical heating elements (B 82), drawn or rolled alloy, 60 per cent nickel, 16 per cent chromium (B 83). The supplement is furnished with orders for the 1942 compilation and copies are available separately at 40 cents each.

Cement:

The new edition of this publication, scheduled for late May, 1945, is considerably more extensive than earlier editions due in part to the establishment as separate standards of some of the tests for cements instead of the former procedure whereby they were combined into widely used Standard C 77. Now procedures for tensile strength, soundness, fineness, etc., are issued separately. This gives all specifications and tests in this field, developed by Committee C-1, and includes the Manual of Cement Testing and also lists better known and more important sources of information on portland cement. 150 pages. $1.00 to A.S.T.M. members, list price $1.50.

Rubber and Rubber-Like Materials:

More than 70 standards and tentative standards provided in this new compilation (June, 1945) cover all kinds of rubber products—gloves, wire and cable, cements, hard rubber products, etc., and show the large number of testing procedures developed by Committee D-11 involving chemical methods, the more commonly used physical tests (hardness, tensile, adhesion, tear, cure, etc.) and many special procedures for specific products. Greatly enlarged, the volume covers almost 500 pages. Available to members at $1.80 each, list price $2.75.

Soaps and Other Detergents:

Changes and modifications in the specifications and methods of testing soap have justified the new edition of this compilation which gives some 30 standards in this field. It was developed by Committee D-12. Available late in June, this 160-page book can be obtained by members at $1.00 per copy, list price $1.50.

Plastics:

Some idea of the growth in the Society's work in the field of plastics, including materials used for electrical insulation, is given by comparing the number of pages in the first edition of the compilation issued in May, 1943, 380, with the edition now on press covering some 550 pages. There are about 100 specifications and tests given in their latest form, including, of course, many new items published in recent months for the first time. The work of the Society's Committee D-20 has received widespread recognition and a review of this new book will indicate that the recognition is justified. In heavy paper binding, the book is available to members at $1.80, list price $2.75. Available late in June.

List of Standards; Index to Standards

PENDING publication of the Index to A.S.T.M. Standards as of December, 1944, a 224-page publication now being ready for press, members may find it of service to request a copy of the 48-page List of Standards. This pamphlet, particularly convenient to indicate just what standards are available under such broad headings as steel, cement, etc., is found very useful in answering inquiries about our specifications. It is not intended to be a substitute for the complete Index, which under a great many appropriate headings gives the title and designation of the respective specifications and tests. Furthermore, the Index gives a page reference to the book where the items are published and it also includes a list in numeric sequence of the serial designations. Each member will receive a copy of the Index to Standards sometime in June and the book should be placed adjacent to the 1944 Book of Standards. As copies of the Index are distributed on request, each year several thousand purchasing agents, materials engineers, and technologists not affiliated with the Society get the publication, which is useful to them in a variety of ways.

Petroleum Tests

IN AN article entitled "Twenty-five Years of Work Developing Testing Methods for Petroleum Products," appearing in the January API *Quarterly*, David V. Stroop, Staff Engineer, American Petroleum Institute, recently appointed Acting Secretary of A.S.T.M. Committee D-2, outlines the history of the development of testing methods for petroleum products. The early history, before the formation of Committee D-2, was similar to conditions existing in many other industries, with all shades of opinions and thoughts on standards, although there was a realization of the importance of having some recognized standards. A.S.T.M. organized its Committee D-2 on "Methods of Testing Lubricants" in 1904 and numerous proposed methods were developed, but it was not until 1917 that the various methods were agreed on and published. The importance of this work was recognized by the American Petroleum Institute and following its first meeting in March, 1919, Dr. Van H. Manning, Director of the Federal Bureau of Mines, was asked to serve as Chairman of an A.P.I. Committee. The following year Dr. Manning became Director of Research of the Institute and this same year A.S.T.M. enlarged the scope of this committee to include all petroleum products, the original title having covered only standard tests for lubricants. Many members of the A.P.I. have been and are still active in A.S.T.M. work in this field, including T. G. Delbridge, K. G. Mackenzie, J. B. Rather, and many others. Probably no A.S.T.M. group has had more influence in its field both from the standpoint of producers and consumers than has Committee D-2. In this work there has been very close cooperation between the A.P.I. and the Society.

Cancellation of Emergency Steel Orders

As of April 28, most of the schedules to the Limitation Order L-211 involving National Emergency Specifications for Steel Products were cancelled, the general revocation order stating that "Schedule — to Limitation Order L-211 is hereby revoked. This revocation does not affect any liabilities incurred under the schedule."

The schedules cancelled affect the following materials:

Schedule	
1	Concrete Reinforcement Steel
2	Steel Wheels and Tires
4	Structural Steel Shapes
5	Steel Axles and Forgings
6	Mechanical Steel Tubing
7	Rails and Track Accessories
8	Carbon Steel Plates
10	Water Well Tubular Products
11	Steel Pressure Pipe
12	Steel Pressure Tubes
13	Steel Pipe
14	Steel Fence Posts
15	Hot-Rolled Carbon Steel Bars

Cancellation of these orders starts to ring down the curtain on a most interesting phase of wartime activity in which large numbers of A.S.T.M. members most of them serving on the Society's Committee A-1 on Steel participated. This work was inaugurated in the Fall of 1941, and continued intensively during the next 18 months with the primary objective of focusing production on a limited number of specifications thus aiding the mills in getting out maximum production. The work was sponsored under WPB auspices by three cooperating groups: the Society of Automotive Engineers, American Iron and Steel Institute, and A.S.T.M., with the Army and Navy very closely participating.

Many Emergency Alternate Provisions (pink slips) and several Emergency Specifications issued by A.S.T.M. resulted from this wartime activity and in the next few months Committee A-1 on Steel must institute studies of these to determine which might well be retained and incorporated in the specifications involved. All of these pink slips and the Emergency Specifications are incorporated in the 1944 Book of A.S.T.M. Standards, Part I, Metals.

Vice-President Townsend Appointed Materials Engineer at Bell Telephone Laboratories

Many A.S.T.M. members will be interested in changes in the organization of the technical staff at Bell Telephone Laboratories, Inc., one of which is the appointment of the Society's Senior Vice-President, J. R. Townsend, and nominee for President, 1945–1946, as Materials Engineer. In this expansion of his responsibilities, Mr. Townsend is concerned with selection of the diverse materials required in the development of the apparatus and equipment of the telephone plant, development of processes and specifications.

The April issue of the *Bell Laboratories Record* discusses the changes in the Chemical Laboratories in which has been consolidated the former Materials Standards Dept., thus bringing together those concerned with chemical and metallurgical research and materials engineering. R. M. Burns, formerly Assistant Chemical Director, has been appointed Chemical Director, reporting to the Director of Research, and R. R. Williams, former Chemical Director, is now Chemical Consultant. Mr. Townsend will report to Mr. Burns as second in charge of the combined organization.

The *Record* points out that

"The selection of materials for engineering purposes is but one aspect of the work of the enlarged Chemical Laboratories. It will be necessary for this group to continue to define the level of quality desired in these materials, to develop suitable tests and testing procedures for the establishment of this quality and finally to embody these in specifications, the use of which will provide assurance that the materials will meet the requirements of service.

"Fundamental research will be continued in chemistry and metallurgy for the purpose of increasing our basic knowledge of the relationship between the composition and structure of materials and their properties and behavior in telephone applications. Problems of aging, corrosion, and degradation which are the results of reactions with elements of the surrounding environment must be understood in order to be controlled. Our unique interest in the behavior of materials in electrical fields which depends upon such things as molecular constitution, atomic configuration, and electronic energy has led to programs of fruitful research. A relatively simple chemical compound has often found a multiplicity of uses as apparatus and circuit elements. As the telephone system has grown in complexity, it has become increasingly necessary to carry on exploratory and engineering studies in the whole materials field in order that we may be in a position to request of outside industries the kinds of chemical compounds or alloys having highly specific properties which are required. As the trend toward new developments continues in the postwar period, so also will the need of new and better things from chemistry and metallurgy."

Inter-American Standardization

In announcing the appointment of Edmund A. Pratt as Director of its Inter-American Department, the American Standards Association refers to the close collaboration established with existing national standardizing bodies of Brazil, Mexico, Argentina, and Uruguay, and notes the momentum with which the standards movement of Latin America is moving. New standards groups are being formed in Cuba and Chile.

Until recently Project Manager for Pan American Airways, Inc., on assignment in Brazil and a former Manager of Overseas Sales for the Barber Asphalt Co. and Managing Director of one of its English subsidiaries, Mr. Pratt has had wide experience in commercial transactions abroad. The Department under his direction is expected to intensify its present program of cooperation with Latin American organizations and to expand in various directions, including distribution of standards and related information to the Latin American countries in their respective languages.

Y Especificaciones de la A.S.T.M.

The title of this article is quite clear to anyone whether a student of Spanish or not and is used to direct attention to a full-page advertisement in the newspaper *El Mercurio* of Santiago de Chile, April 9, 1945, where a company Madeco, formerly Mademsa, a leading manufacturer of copper, uses the following in its advertisement:

Todos nuestros productos son fabricados de acuerdo con las normas y especificaciones de la "A.S.T.M.", lo que garintiza una calidada uniforme.

which means according to our Spanish that "all of our products are fabricated in accordance with the standards and specifications of the A.S.T.M. which guarantees a uniform quality." This page was received from E. A. Pratt, Manager, International Relations, American Standards Association, to whom it was mailed in turn by C. T. Brady, American representative in South America.

Pending Actions on Steel Castings and Pipe

At meetings of two of the steel committee's largest groups, Subcommittees VIII on Steel Castings and XXII on Materials for High Temperature Service, a number of recommendations were accepted, subject to confirming letter ballot, which eventually should result in important new tentative specifications and revisions in existing standards. Based upon rather exhaustive study by the Steel Founders' Society, Subcommittee VIII contemplates recommendations which will reduce the number of standards in this field. For example, the current standards A 27, A 87, and A 215, covering miscellaneous industrial, railroad, and castings for welding, will be combined into one document entitled "Mild to Medium Strength Carbon Steel Castings for General Application." Eight grades are proposed with physical requirements ranging from 60,000 to 70,000 psi. tensile strength, with elongation from 20 to 24 per cent. Certain grades are indicated as especially suitable for welding. Changes in the existing requirements for high-strength castings for structural purposes (A 148) involve the elimination of one grade and some changes. Here the physical requirements range from 80,000 to 175,000 psi. with yield points from 40 to 145 psi. The study has resulted in a number of other modifications which involve heat treatment, testing requirements, etc., all designed to bring the requirements in line with best modern practice.

In the high-temperature field, there are several castings specifications under study, and one of these on the recommendation of Subcommittee XXII Castings Section will incorporate a new grade designed to retard possible graphitization at high temperatures. This will be a chromium-molybdenum composition with the chromium content around 0.40 to 0.70 per cent and molybdenum 0.40 to 0.60 per cent.

The subject of graphitization has been discussed exhaustively through technical papers and reports, primarily in the interest of furnishing material for power plants and related installations that will not tend to graphitize into the form of chains of graphite in heat-affected zones, such as welding might induce, after long periods at high temperatures. Studies have been made by many of the utilities and research institutions with final results still to be announced, but rather strong evidence to warrant the new pipe specification approved by Subcommittee XXII providing for a chromium-molybdenum composition, rather rigid requirements on manufacture and testing of the pipe, but in particular specifying a coarse McQuaid-Ehn grain size, which is incorporated to make sure that low aluminum steels will result. The current Tentative Specifications A 206, covering a chromium-molybdenum grade for service up to 1000 F. is being continued. There has been quite a bit of evidence showing that this has graphitized in some installations, but at other plants, none has developed. There is some feeling that up to 750 F., carbon steels might be used, and above this the new chromium-molybdenum composition (chromium 0.40 to 0.60 per cent; molybdenum 0.45 to 0.65 per cent). There is rather convincing evidence that metallic aluminum might favor the development of graphitization, and further that chromium counteracts this tendency so the committee has in a sense two defenses—one the grain size limitation, the other the alloy addition.

In all of the high-temperature specifications, the committee will recommend the deletion of references to specific temperatures, leaving information on design values and limiting temperatures specifically to code writing groups.

In the Tentative Specifications A 106, which have covered lap-welded and seamless pipe, the requirements on lap-welded material will be entirely eliminated, since Specification A 53 provides a satisfactory grade.

In bolting, where the alloy steel Specification A 193 is widely used and Specification A 96 also has been widely applied, a combination will be effected, so that the three grades now in Specifications A 96, based on physical properties with chemical requirements optional by the manufacturer, will be incorporated in Specifications A 193. Other changes were acted on to clarify other requirements.

All of these items, it is expected, will be referred eventually to the main Committee A-1 on Steel, and thence to the Society's Committee E-10 on Standards for final action.

Another development in the steel committee involves Specifications A 254 for copper-brazed steel tubing. On the basis of current requirements, stress values were assigned that were considered not at all indicative of the potential properties in certain types of material, and accordingly the different processes of manufacture are to be differentiated so that more rational design and stress values can be assigned.

In connection with castings, it is of interest to note the development in a special group of the S.A.E. Iron and Steel Division, permitting purchase of castings on hardenability and other requirements. This work is being carried out cooperatively with A.S.T.M.

Much Activity in Committee D-7 on Wood

Committee D-7 on Wood met at The Palmer House in Chicago on April 11, 1945, with Chairman Hermann von Schrenk presiding. This year Dr. von Schrenk, a Past-President and Honorary Member of the Society, will have been chairman of this committee for 41 years.

One of the first actions of the committee was to prepare a suitable memorial for Cloyd M. Chapman, another Past-President and Honorary Member, whose death was recorded in our August, 1944, Bulletin. He had long been active in the affairs of Committee D-7.

Subcommittee I on Specifications for Timber reported that no changes were being made in current specifications, but revisions are contemplated in which the question of increased working stress is under close analysis.

Subcommittee IV on Wooden Paving Blocks is contemplating

writing specifications for wooden paving blocks for interior use. There are important applications of this product in many large industrial plants.

Although the subcommittee on timber preservatives contemplates no immediate revision in its eight current specifications, it is considering the preparation of new specifications for various preservative salts and also the enlargement of analytical methods as, for example, the method of determining zinc. It was noted that many data will be needed as to the actual test results showing the behavior of various formulations for preservatives as given in the Federal specifications before they can be adapted to A.S.T.M. standards. It was also recommended that study be made of the effectiveness of laboratory decay tests on treated blocks as a means for evaluating preservatives along the lines suggested in British specifications.

The Tentative Methods of Testing Veneer, Plywood, and Other Wood and Wood-Base Materials (D 805), approved on August 28, 1944, cover procedures for the following tests: Compression, static bending, tension, F.P.L. (Forest Products Laboratory) panel shear, F.P.L. plate shear, toughness, hardness, moisture content, and specific gravity. Subcommittee IX on Methods of Testing expects that there may be revisions during the coming year and that some additional procedures such as methods for conducting plywood glue shear strength tests and moisture absorption will be included. Also under preparation are revisions of A.S.T.M. Standard Methods of Testing Small Clear Specimens of Timber (D 143 – 27), to include some modification and clarification of sampling procedure, the revision of the tension-parallel-to-grain test method, and enlargement to include some additional tests.

Subcommittee X on Nomenclature and Definitions has proposed a definition for brashness which after some consideration has been written as follows:

Brashness.—A characteristic or a condition that causes some pieces of wood to be relatively low in shock resistance, and when broken in flexure, to fail abruptly without splintering and at comparatively small deflection.

A revised list of species names as given in the Standard Definitions D 9–30, which conform to recent revisions of tree names by the Department of Agriculture and the U. S. Forest Service, was also approved.

The subcommittee on moisture content of timber has been working on standards which would cover a complete variety of methods of making moisture determinations. Some difficulties and limitations were discussed, particularly the questions of accuracy and of restricted range. It is planned to publish a discussion of the procedures as information in the annual report of Committee D-7 prior to recommending their acceptance as tentative.

Subcommittee XII on Fire-Retardant Wood has given considerable thought to the problem of attempting to establish the purpose of fire tests with respect to the basic problem of measuring fire spread, flame penetration, or fuel contribution. Much work remains to be done but a summary of activities to date will be included in the annual report of the committee.

The general plans for reorganization and enlargement of the work of Committee D-7 were discussed by the chairman and by the secretary, L. J. Markwardt, U. S. Forest Products Laboratory. Three new subcommittees have been established: II on Laminated Timber; III on Plywood; and VIII on Modified Wood and Wood-Base Materials. A number of new appointments have been made to broaden the membership structure and a complete review and revision of subcommittee membership has been accomplished.

Committee on Electrical Insulating Materials

MANY of the actions taken at the numerous meetings of Committee D-9 on Electrical Insulating Materials and its subcommittees in Atlantic City, March 13 to 15, will be referred to the Society for approval, many for action by Committee E-10 on Standards. New problems were discussed, and the committee's usual extensive docket of round-robin tests and other cooperative research investigations is continuing.

For years, intensive work has been under way on insulating oils, and a paper is being prepared presenting the results of a recent extensive survey covering the deterioration of transformer oils in use. It is hoped this can be published by the Society in the near future. The group hopes to develop a symposium on testing of insulating oils to be held at one of the Society's future meetings.

Among the recommendations is a proposed new tentative method for determining gas content of insulating oils and the committee also announced that an addition to its series of statements on the significance of tests would cover electrical resistance. These statements have been published in the compilation of standards sponsored by the committee. Additional revisions for publication as tentative are to be issued in the Methods for Testing Electrical Insulating Oils, D 117. Changes already published in the back of Part III of the 1944 Book of Standards pertain to the dielectric strength. The rather frequently revised methods of testing Molded Materials Used for Electrical Insulation (D 48) are again to be improved with certain changes, and revisions will also be made in the methods of testing varnished cloths and varnished cloth tapes used in electrical insulation (D 295), and methods of testing flexible varnished tubing used for electrical insulation (D 350). Varnished tubing refers to braided cotton sleeving coated, or impregnated and coated with varnish, lacquer, or a combination of lacquer and varnish, or similar coatings. The term "saturated sleeving" refers to braided cotton sleeving impregnated with varnish but the coating need not be continuous as it is for varnished tubing. Other standards where

changes are contemplated include methods of sampling and testing untreated paper used in electrical insulation (D 202), natural block mica and mica films suitable for use in fixed mica-dielectric capacitors (D 748), and methods of conditioning plastics and electrical insulating materials for testing (D 618). In connection with this latter proposal, a joint subcommittee which functions for Committees D-9 and D-20 considered revisions in detail. The discussion developed two philosophies regarding the handling of Methods D 618, as follows:

"(*a*) To adopt the Standard Laboratory Atmosphere (50 per cent relative humidity at 25 C.) as a single standard and consider all other procedures as primarily functional, to be specified in methods of test or specifications where functional conditioning is indicated, and (*b*) to include at least one functional procedure now in wide use for testing substantial quantities of plastics and thereby recognize existing practices. This school of thought appreciates the value of a single standard but feels that Methods D 618 will be a more useful document if the accepted single standard is accompanied by functional procedures.

"A substantial majority decided to send to Committees D-9 and D-20 letter ballot the revision as prepared, containing the Standard Laboratory Atmosphere, and a functional procedure calling for drying at 50 C. for 48 hr. It should be kept in mind that in common with all A.S.T.M. procedures, Methods D 618 are subject to as frequent revision as the subcommittee feels desirable in order to maintain a delicate balance between the idealized objectives which we all hope for, and those realistic compromises frequently necessary to make our methods useful to a great number of people.

"Under Standard Test Temperatures a rather comprehensive array of temperatures is given. This represents a combination of civilian and military usage. It may be possible to discontinue some of them after the war."

Twenty Proposed Standards in the Field of Industrial Aromatic Hydrocarbons

BASED on intensive work in its subcommittees, plus numerous comments received as a result of widespread circularization of the proposed specifications and tests, A.S.T.M. Committee D-16 on Industrial Aromatic Hydrocarbons, which was organized just a year ago, will shortly submit for letter ballot of the committee eight proposed methods of test and twelve proposed tentative specifications. This action was approved by the advisory group at its meeting early in April in New York. In addition the committee will submit for publication in its annual report information resulting from the series of cooperative distillation tests.

The test methods and specifications in course of approval are as follows:

Methods for:

- Determining Refined Water White Constituents in Light Oil
- Specific Gravity, Color, and Hydrogen Sulfide and Sulfur Dioxide Content (Qualitative)
- Distillation
- Acidity Wash of Benzene, Toluene, Xylene, and Similar Aromatic Hydrocarbon Products
- Acid Wash of Benzene, Toluenes, Xylenes, and Similar Industrial Hydrocarbons
- Solidifying Point of Benzene
- Paraffins
- Copper Corrosion Test

Specifications for:

- Nitration Grade Benzene
- Industrial Grade Benzene
- Nitration Grade Toluene
- Industrial Grade Toluene
- Nitration Grade Xylene
- Five Degree Xylene
- Industrial 90 Benzene
- Industrial Xylene
- Ten Degree Xylene
- Refined Solvent Naphtha
- Crude Light Solvent Naphtha
- Crude Heavy Solvent Naphtha

Many Actions from Plastics Committee Meeting

MANY interesting developments took place at the series of meetings held by Committee D-20 on Plastics and its subcommittees in Atlantic City, March 14 to 16. Some notes appear below from which it will be seen that proposed new standards, revisions of existing specifications and tests, and considerable research involving methods of testing and related items are in prospect.

The pace at which this committee has been functioning has put it among the forefront of A.S.T.M. groups and there is no justification for assuming that it will not continue as one of the hardest working technical committees. These notes wil confirm that impression.

Strength Properties:

Activities here involve tensile and compressive properties, impact, shear, flexure, and bearing strength. Work on compressive buckling of long columns is to be evaluated and tests of low density sandwich type materials may be considered. A new method of tension testing of thin films will be submitted to letter ballot.

Revisions in the method of impact testing are in course of approval. An extensive research project concerns a ball impact test involving 150 samples of polystyrene and other materials. Round-robin tests will be made. Research is anticipated on low-pressure laminates (including the glass cloth type) which would be evaluated from the standpoint of impact, compression, and bonding strengths. Several laboratories are cooperating in shear tests and work is under way on the subject of flexure. Cooperative tests will be started on bearing strength, and in the field of nonrigid plastics, flexible tubes will be investigated for strength.

Hardness Properties:

Based on studies of A.S.T.M. and certain Government standards, a Rockwell testing procedure has been drafted and is now out to letter ballot. Important points covered include the major load, the time of reading, limit of the M scale, etc. The subcommittee considered a report listing Rockwell values determined by two different procedures on 34 different plastics. On scratch

hardness, a table showing test results on 26 samples, consisting of indentation, scraping and falling abrasive tests, was considered. Certain methods have been developed. The proposed test for breaking resistance is to be rewritten and again submitted for ballot.

Thermal Properties:

Changes in the Test for Deformation Under Load at Elevated Temperatures (D 621) are being circulated and also a new test for coefficient of cubical expansion. Section C was directed to study new methods of testing for determining the heat- or flame-resistant characteristics of the more resistant types of plastics such as the asbestos- and glass-filled materials. Possibilities of determining the ignition temperatures of the more flammable types of plastics are also to be investigated by this section. An interesting discussion was presented on a recording type of heat distortion apparatus which would obtain temperature *versus* deflection curves.

Optical Properties:

There was lively discussion on the Tentative Method D 672, haze of transparent plastics by photoelectric cell, and important changes are to be submitted. The lower range of haze will be changed from 1 per cent to 3 per cent, reference to use of the method for light transmission measurements will be deleted, new drawings will be prepared covering the required optical geometry without other details, and requirements on setting the instrument to a suitable photoelectric cell will be incorporated. After a proposed referee method of measurement of haze with a spectrophotometer is redrafted, it will be submitted to round-robin test checks. Whether a new method for measuring haze below 3 per cent was advisable came in for discussion and a method using an integrating sphere is to be drafted and affiliated. This may have possibilities for determining light transmission. For testing surface irregularities, one method for measuring the deviation of line of sight is to be prepared and submitted for ballot.

Permanence Properties:

In this field many problems confront the development of a satisfactory test for weight loss on heating. Two drafts have been prepared and other possible testing procedures are now to be considered. A questionnaire relating to the effect of water is being circulated to determine just what sort of tests and what kind of permeability constants are desired.

Specifications:

In this most active subcommittee, revisions are being submitted to the Society in the specification requirements for cellulose acetate (D 786), new specifications for cast allyl plastics, and the group is considering by letter ballot changes in the phenolic specifications (D 700) and new requirements for polystyrene sheets, plates, and rods. It was decided to use flow temperature as the sole criterion of classifying methyl methacrylates into grades. This group has under way round-robin tension tests of ethyl cellulose, and additional values are to be included in the specifications for nonrigid polyvinyl chloride (D 742).

Analytical Methods:

Extensive work continues in the relatively new field of analytical procedures with tests on determining insolubles in polystyrene, and a new procedure for determining free phenol and free formaldehyde is to be sent out for approval. Cooperative tests on determination of plasticizer in cellulose ester plastics have been prepared and will be checked. A procedure for synthetic resin impregnants will be balloted on. Other work involves ammonia in closure materials and extraction method for phenol-formaldehyde resins.

Research:

Interesting discussions were presented on evaluating flow characteristics of plastics with speakers covering the use of a flat plate plastometer and a multiorifice compression mold. The other problem considered, namely impact testing, involved various notching procedures, since it is believed that small variations in the shape of the apex of the notch as well as scratching and "cold work" can have a large effect on impact strength.

Another source of discrepancies is encountered when the characteristics of a plastic are such that the velocity of impact in the test causes the fracture to fall between "tough" and "brittle" in its nature. Wide variations can be eliminated by testing at lower velocities, when the resin will break in a tough fashion, or at higher velocities for brittle fracture. In some instances the velocity change during impact may be large enough to initiate a brittle fracture which changes to tough before completion. Changing temperature was said to have a similar effect to a change in velocity. Sections have been appointed to prepare programs for investigating the impact testing and several committee members will cooperate.

Conditioning:

See accompanying article on activities of D-9 on Electrical Insulating Materials.

Electrical Research

AN INTERESTING 64-page brochure has been received from the British Electrical and Allied Industries Research Association, London, entitled "Co-Operative Electrical Research." This describes in some detail the E.R.A. and its activities, in particular how the E.R.A. is related to the electrical supply industry and the manufacturer, but the major portion of the book covers in some detail the E.R.A. researches. Much of the activity relates to insulating materials, but the activities are not confined to this particular field.

The Association has been a member of the Society for many years; their former Director of Research, E. B. Wedmore, who retired on December 31, 1944, was a member of A.S.T.M. Committee D-9 on Electrical Insulating Materials. This membership is continued in the name of A. E. Tooke, who is Superintendent of the Information Bureau, Dr. S. Whitehead being Acting Director as of January 1, 1945. Copies of this well-illustrated publication can be obtained by A.S.T.M. members who are interested, by writing on their company stationery to Mr. R. A. McMahon, Secretary, E.R.A. Headquarters, 15 Savoy St., London, W. C. 2, England.

Administrative Committee on District Activities

A NEW Administrative Committee on District Activities was formally organized at a meeting held in Detroit on May 15. It has been apparent to the Executive Committee for some time that a separate committee, charged with administration of district activities, and acting as a consulting and advisory group to the various districts, would be very desirable, and at the same time, the committee could establish policies based on the needs of the respective districts, and help in effectuating these with the local officers. Previously, the district work has been reviewed periodically by a subcommittee of the Executive Committee, which now has transferred its responsibilities to the new group.

The personnel as noted below, includes men who have been very active in A.S.T.M. affairs and, further, who are conversant with district problems through service on district committees; they also represent tie-ins with various other associations, so that when desirable contacts may be established with other groups.

ADMINISTRATIVE COMMITTEE ON DISTRICT ACTIVITIES

C. H. Fellows, *Chairman*, Head, Chemical Div. Research Dept., Detroit Edison Co., Detroit, Mich.

Theo. P. Dresser, Jr., Chief Engineer, Abbott A. Hanks, Inc., San Francisco, Calif.

W. H. Lutz, Technical Director, Pratt & Lambert, Inc., Buffalo, N. Y.

J. deN. Macomb, Assistant to Vice-President, Inland Steel Co., Chicago, Ill.

R. W. Orr, RCA Victor Div., Radio Corporation of America, Camden, N. J.

F. G. Steinebach, Editor *The Foundry*, Vice-President and Secretary, Penton Publishing Co., Cleveland, Ohio.

At present there are ten District Committees in leading industrial centers, and others have been authorized. Over the years the committees have sponsored very successful and interesting meetings, and a number of publications have resulted as well as individual papers that have appeared in the BULLETIN. The districts have aided in other A.S.T.M. affairs; for example, constituting a committee on arrangements when annual or spring meetings have been held in their areas.

DISTRICT CHARTER, MANUAL, ETC.

At its first meeting, the new administrative group reviewed in detail proposed changes in the Charter covering district committees, and also a Manual which is intended to be a compendium of good practice. Numerous other suggestions and problems were discussed and evaluated.

As the work of the Society expands, there will be a number of matters where Districts can continue to be most helpful. At the moment, for example, there is the possibility that some of the Districts will arrange to have papers, normally scheduled for presentation at the annual meeting, given by the authors at meetings arranged locally; this will provide an opportunity for discussion and comment, and have other advantages.

R. W. Orr

J. de N. Macomb

W. H. Lutz

C. H. Fellows

T. P. Dresser, Jr.

F. G. Steinebach

Messrs. Bates, Mochel, and Warwick Speak at Buffalo and Cleveland Meetings

AT LOCAL meetings arranged by the A.S.T.M. District Committees in Buffalo and Cleveland on March 28 and 29, President P. H. Bates and Secretary-Treasurer C. L. Warwick spoke; N. L. Mochel, Manager, Metallurgical Engineering, Westinghouse Electric Corp., Chairman of Committee A-1 on Steel and of the Joint Committee on Effect of Temperature, gave his interesting talk, "Shall It Be Cast? Forged? or Welded?" and in Buffalo, Dr. C. C. Furnas, Director of Research, Airplane Div., Curtiss-Wright Corp., joined Mr. Mochel as a technical speaker covering "Future Trends in Aviation." Brief notes on the three technical talks appear below. Mr. Warwick discussed recent developments in A.S.T.M. In Buffalo, District Vice-Chairman O. W. Ellis presided at the afternoon session and Chairman B. L. McCarthy at the dinner and evening session, while in Cleveland Chairman A. J. Tuscany presided, introducing in an interesting manner the speakers and others present.

Considering the time of the meetings, just before Easter, and other factors, the attendance was considered favorable, and all those present showed sustained interest in the program.

With these meetings, President Bates has visited within the past year and a half eight of the ten districts.

In Buffalo, District Secretary T. L. Mayer handled the many arrangements for the dinner and technical sessions, and in Cleveland, Secretary R. T. Bayless carried out similar functions in an equally efficient manner.

Castings *vs.* Forgings *vs.* Weldings

N. L. Mochel, Manager, Metallurgical Engineering, Westinghouse Electric Corp.

In his interesting discussion on this subject, which many may consider a controversial one, Mr. Mochel, who makes widespread use in his work of all three processes, said that during wartime, particularly as the production tempo was accelerated, we made use of welding, forging, and casting, all three, at top speed, and even then, had difficulty in satisfying the hunger of Mars. He stated his conviction, bulwarked by discussions with associates and other materials engineers, that unquestionably the most important activity or development in wartime metallurgical achievements was the widespread and successful use of welding.

During the past two or three years there have developed black marks against all three methods. Forgings, for example, have shown unsound centers in ingots. There has been dirty steel, considerable slag at times, with thermal cracks and flakes. In castings, shrinkage defects have been bothersome; there have been tears and holes, and sand inclusions. And, in weldings, we have had broken ships, laminations in plates, unsound welds, etc.

Mr. Mochel illustrated his discussion with an extensive series of slides, most of which were from the heavy machinery field. He cited cases where one or the other of the processes would most certainly continue to be used. For example, huge locomotive bed frames, because of their complicated shape and size, would continue to be cast. He mentioned a quite remarkable development—a cast-steel breech ring, with its savings in man hours and machine tool hours. In much of the electrical machinery, welding has replaced cast iron and cast steel for many of the parts. There has been some use of centrifugally cast shafting for ships instead of forged shafting. Primarily, however, his thesis was that the designers and fabricators can most effectively use two or all three methods. He mentioned a merchant ship main drive, one of the C-3 craft, where the surface condenser and turbine mountings were welded; also the reduction gear casing. The turbine cylinders were cast, and the pinions, turbine rotors and other parts were forged—the whole making a compact, sound assembly.

Another case was a cast-steel carbon-molybdenum steel throttle valve body for very high pressure and temperature, in which the steam chest was forged; the elbows and manifolds welded to it—another three-process job.

He stressed the necessity of designers carefully considering processes before they are too far along in the work, and here the metallurgist and practical fabricator can be of assistance—in fact, they are essential. He concluded with the theme that the accepted meaning of the word "*versus*"—castings *versus* forgings *versus* welding—was "against, or a striving against," but that there was a second meaning, which means "toward, or traveling in the direction of," and that this might well be the condition in the years ahead, where we shall have many applications which can best be met by taking all three of the processes and combining them. There will be "keen competition and yet intelligent coordination in the years ahead."

Notes on the National Bureau of Standards

P. H. Bates, Chief, Clay and Silicate Products Div., National Bureau of Standards

Since it would have been impossible to describe adequately all of the vast amount of work under way at the National Bureau of Standards, Mr. Bates confined his remarks to research on materials. He referred to the importance of establishing standards of measurement, such as length, mass, and the like, and then he referred to the broad functions of the Bureau, namely, commercial standardization, research and testing, and then described the divisions in the latter activities which are as follows: Electricity, Weights and Measures, Heat and Power, Optics, Chemistry, Mechanics and Sound, Organic and Fibrous Materials, Metallurgy, and Clay and Silicate Products.

During World War I, and World War II particularly, but even during peacetime, the Bureau manufactures optical glass for the Government, particularly the U. S. Navy, and this work has been intensified during the past two or three years. Mr. Bates described some of the problems in connection with glass—the high refractive index and dispersion that are required, freedom from flaws, and he then explained the various prisms that are necessary. One example was the type of glass used in binoculars. He touched briefly on the various kinds of optical glass required, and mentioned the fact that production had not been developed commercially because of the relatively low demands for it in peacetime and the cost factor involved.

Future Trends in Aviation

Dr. C. C. Furnas, Director of Research, Airplane Div., Curtiss-Wright Corp., Buffalo, N. Y.

Dr. Furnas, first of all referred to the many ramifications in this subject. To narrow his field, he discussed three questions—all pertaining to the commercial field—and covering the post-war period, say about 1950. The questions concerning the planes—

1. How Large?
2. How Fast?
3. How Many?

He predicts that the planes will not be huge, *but* there is no technical reason why they should not be. The economic questions of pay loads, much as with our ocean vessels, will be the governing factor, plus the question of frequency of service. Apparently the faster we go, the more frequency of service we must have, according to the public trend. In short, if there were two planes a day, we wouldn't mind missing one or two, but if there were one an hour, we'd just have to make the very next one!

The workhorse plane will probably carry from 40 to 50 passengers, similar to the present DC 4. A smaller trunk line would probably use a 20 to 25-passenger plane; feeding both of these will be a 10 to 15-passenger plane. For high-speed, *de luxe* service, coast-to-coast, for example, perhaps planes carrying from 80 to 100 passengers would be used. Concerning speed, Dr. Furnas suggested we might hope for the *de luxe* faster planes to travel at about 300 m. p. h., with slower speeds probably in prospect.

The audience was particularly interested in Dr. Furnas' analysis with respect to the number of planes. In 1940, travel data showed a billion passenger miles during the year, using 335 planes, mostly of the DC 3 type; approximately seven billion passenger miles in Pullmans (7500 cars); and in coach travel, 13 billion passenger miles. The air lanes in 1942, with only 165 planes, far exceeded the 1940 passenger figure, and in 1944, with 279 planes, had a record of about two and one-half billion passenger miles. Possibly by 1950 there may be an increase of 700 per cent in passenger travel, perhaps 900 per cent in mail, with a tremendous cargo boost of over 3000 per cent. This gives a mean of about 850 per cent, and to handle this, it is thought the air lanes would need about 600 planes. There would probably be a similar number of planes in international service and foreign-sponsored lines would have about the same number. He dwelt on the automotive theme for a moment, showing that in 1910 with over two million cars, the industry felt that seven and one-half million more would be the maximum, but here in 1940 we had 30 million.

In the field of development, he dis-

cussed four "aces," which undoubtedly would have a great impact on the aircraft industry. In first position was radar, making possible the maintenance of schedules; second, the gas turbine, with its relatively light weight and potential heavy pay load. The third item was jet propulsion, and, fourth, the helicopter, which he stressed particularly from the standpoint of safety.

Northern California Members Participate in Welding Meeting

MEMBERS of the American Society for Testing Materials living in Northern California were invited to attend a dinner meeting of the American Welding Society's Section at the Engineers' Club, San Francisco, on the evening of March 26, 1945. The speaker of the evening was LaMotte Grover, Welding Engineer, Applied Engineering Dept., Air Reduction Sales Co., New York. Mr. Grover is an A.S.T.M. member and has been active in the Society's technical committee work. His subject was "The Design and Construction of Arc-Welded Steel Structures." The talk was illustrated by slides. As a supplementary feature a sound film was run showing arc welding of stainless steel. There was an attendance of about 165 nearly half of them being nonmembers in the Welding Society Section.

In addition to the instructive value of Mr. Grover's talk and the showing of the film, the A.S.T.M. members who attended were shown the courtesy of being introduced by the speaker, mention being made of their membership in the Society. In San Francisco there is so much intermingling of persons engaged in technical work that an individual always finds himself among friends and acquaintances no matter which of the technical meetings he may attend.

Arrangements for the attendance of members at this meeting were carried out by Dozier Finley, The Paraffine Cos., Inc., *Chairman*, and P. V. Garin, Southern Pacific Co., *Secretary*, respectively, of the A.S.T.M. Northern California District.

Chicago District Active in War Production Conference

MANY members of the Society participated in the extensive Chicago War Production Conference held on March 29 in Chicago sponsored by the Chicago Technical Societies Council, of which A.S.T.M. is a member. The A.S.T.M. District Committee sponsored Panel No. 4 dealing with Inspection and Identification of Materials, with G. E. Stryker, Bell & Howell Co., chairman of the district program committee making arrangements for the three speakers as follows:

Magnetic Particle Inspection—W. E. Thomas, Second Vice-President, Magnaflux Corp.

Thermo-Electric Identification of Steel—Harold Snavely, Staff Engineer, Claud S. Gordon Co.

Description of Some Methods of Making Non-destructive Tests for Physical Properties of Metals—P. E. Cavanagh, Fellow, Ontario Research Foundation, Chief Metallurgist, Allen B. Du Mont Laboratories, Inc.

J. F. Calef, Automatic Electric Co., A.S.T.M. District Chairman, who has been very active in the Technical Societies Council work, was in charge of tickets and registration committee. Past-District-Chairman E. R. Young, Climax Molybdenum Co., was general chairman of the panels dealing with investment castings and magnesium castings; several other Society members presented papers and discussion.

Mr. Stryker served as chairman at the panel session. The attendance was about 200 and comments indicated much interest in the discussions. Abstracts of two of the talks appear below. With reference to the talk by Mr. Thomas, considerable material on magnetic particle inspection was published in the December ASTM BULLETIN prior to the extensive Symposium on Magnetic Particle Testing held in Philadelphia and this symposium with its several papers is in course of publication to be issued this summer. The symposium includes an interesting paper by the late A. V. deForest and C. E. Betz, Magnaflux Corp. Vice-President.

Thermo-Electric Identification of Steel

H. L. Snavely

IN THE early days of steel, each type was easily identified by simple tests and experienced visual examination. But more and more grades or types were introduced to meet specific requirements. By 1940, over 600 grades of ferrous alloys were in common use. The need for precise information regarding the chemical composition of currently used grades of steels has been made more acute with the advent of specialized heat treatments. The relatively long consumption of time in even the so-called "short methods" of chemical analysis made these methods impractical for 100 per cent inspection of even raw stock. More rapid methods were needed to provide for identification and inspection control of material.

Several methods and instruments have been developed to provide the steel man

Southern California District Meeting

A MEETING is being arranged in Los Angeles by the Southern California District Committee, to be held in the Rainbow Room of the Mayfair Hotel on May 28, at 6:30 p.m. Two talks will be presented as follows:

Rocket Development at California Institute of Technology—Frederick Lindvall, Professor of Electrical and Mechanical Engineering.

Rocket Testing—Trevor Gardner, Supervisor of Developmental Engineering for the Rocket Project, California Institute of Technology.

Dr. Lindvall will review the development of rockets at California Institute of Technology, and Dr. Gardner will show design, testing, and production of rockets in colored motion pictures.

Discussion will be presented by Messrs. F. J. Converse, California Institute of Technology, and C. E. Emmons, The Texas Company, both members of the Southern California District Committee. The meeting was arranged through the District Committee Officers, E. O. Slater, Smith-Emery Co., *Chairman;* and H. W. Jewell, Pacific Clay Products, *Secretary*.

with a quick check for identification. Some of the most recent of these utilize the principle of thermo-electricity for their operation. The existence of these so-called thermo-electric currents was discovered by Seebeck in 1821. It was noted, for instance, that if the ends of a copper and an iron wire were fused together and one of the junctions heated, an emf. was generated, and current flowed from the copper to the iron wire.

In 1834, Peltier discovered that when an electric current is passed through the junction of two metals there will be either an evolution or an absorption of heat.

Also, Lord Kelvin concluded that in a closed circuit made up of dissimilar metals there are other sources of emf. than are accounted for by the Peltier effect. His work brought out the fact that a difference of potential exists in a single section of metal when there is a temperature gradient between the ends. This is known as the Thomson emf. The thermocouple emf. is a result of the algebraic sum of the Peltier and Thomson effects.

Several methods of checking steel employing these facts have been successfully used and one is briefly described. It consists of applying resistance heating for a controlled time to a standard steel bar and a bar under test held together at one point. Since the two pieces are heated and then connected to a sensitive galvanometer the resulting deflection may be observed. This is known as the Identometer[1] method. Since the temperature to which the Identometer heats the junction of the reference piece and the unknown piece is constant the emf., if any, is a result of the dissimilarity of the specimens.

It is, therefore, possible with the Identometer to select a bar at random out of a shipment of steel and with this bar pick out all of the remaining bars in the shipment which are identical. The Identometer test consumes only as much time as it takes to clean the steel at the points of electrical contact, make the few connections, and approximately three seconds for the test itself.

If the shipment consisted of three "heats" of steel, the Identometer will show that a certain number of the bars will be identical to the reference piece, another percentage of the bars may cause a movement of the indicator toward the "positive" side of the Identometer scale and a third toward the "negative" side. This groups the shipment into three parts. Then one chemical analysis of one sample from each group will give the chemical composition of every bar in each group.

The ability of the Identometer to check raw stock exactly as to heats is one of its most important advantages. The validity of the Identometer test is not affected in the great majority of applications by the size or shape of the material nor by its surface condition, provided a clean, decarburization-free surface obtains at the points of electrical contact only. Since this instrument is portable and rugged, it may be operated conveniently near the stock piles by means of extension cables and connections.

[1] This instrument is distributed nationally by the Dravo Corp., Pittsburgh; in the midwest by the Claud S. Gordon Co.

Description of Some Methods of Making Non-Destructive Tests for Physical Properties of Metals

P. E. Cavanagh

There are three types of testing instruments now in commercial use which provide a rapid non-destructive means of inspecting metals for various properties. All three of these utilize the cathode-ray tube as an indicating device. The cathode-ray tube provides a practically inertialess indicator. It can be used to examine more than one variable at the same time. These facts have governed its choice as the indicating device for the instruments described and have made their development possible.

The first type of instrument might be called an ultrasonic crack detector. Its major use is in detecting cracks and flaws in metals although it will perform several other functions. This principle is being utilized in several instruments. The Reflectoscope developed by Professor Firestone, University of Michigan, is a general purpose instrument which is being simplified and will be produced commercially by Sperry Products, Inc. A small crystal is used to transmit pulses of high-frequency energy into the piece of metal being inspected. These pulses travel in a straight line through the metal and will reflect from the far side. When they again strike the crystal, a voltage is generated which can be examined on a cathode-ray tube. A distance from the crystal to any reflecting face can be measured on the cathode-ray tube screen. If the metal is sound, this distance will be the thickness of the metal; if it is not sound, a distance measured will be from the crystal to the defect.

General Motors Corp. has developed a very much simplified instrument operating on the same principle to perform one specific job. By tuning the exciting oscillator to resonance, the frequency can be found at which the wave length of the energy introduced into the metal is some exact sub-multiple of the thickness of a thin metal sheet.

The second instrument called the Ferrograph is useful for inspecting magnetic materials for differences in analysis and heat treatment. It utilizes the transformer principle. A very low frequency is fed into a primary coil. Magnetic flux is transmitted by the sample to a secondary coil, and the induced voltage in the secondary examined.

This basic principle has been in use for many years, but improvements embodied in the Ferrograph[1] include the use of a very low frequency which gives some correlation with remnant magnetism, the use of filter circuits to analyze the secondary output and select and amplify the significant odd harmonics, and the use of a special type cathode-ray tube to examine these harmonics simultaneously for differences in both phase and amplitude.

This instrument is useful in distinguishing fairly large differences in analysis of steel and irons and in heat-treating history.

The third instrument, the Cyclograph,[1] is being used in production inspection of a large variety of metals. It is not sensitive to cracks and flaws of any type whatever.

Fundamentally, it consists of an extremely sensitive and stable oscillator. The oscillator output is governed by the characteristics of a test coil whose properties are in turn governed by the magnetic and eddy current losses occurring in a metal sample introduced into the coil. The instrument is a comparator and standard samples of acceptable and undesirable parts must be carefully chosen and the instrument adjusted so that it will distinguish between them. It is essential that the Cyclograph correlate with significant variations in properties regardless of normal production variations in analysis, stresses, or heat treatment.

The oscillator output may be examined on a cathode-ray tube when small numbers of samples are being tested. For inspection of large quantities of pieces, the oscillator output is demodulated and used to operate relays and auxiliary sorting equipment or warning devices.

Fundamentally, the Cyclograph will do only two things: correlate with structure of metal and with stresses within the metal. Since structure is influenced by differences in analysis, differences in heat treatment, and cold working, correlation with structure makes possible a wide variety of commercial inspection jobs for the uniformity of a product.

[1] Produced by Allen B. Du Mont Laboratories, Inc., Passaic, N. J.

Two Sessions at Philadelphia Meeting on Stress Analysis and Modern Design Concepts

INTENSE interest in stress analysis and the modern concepts of proper design were evidenced by the excellent attendance, well in excess of 200, and the questions and discussion during the two-session meeting sponsored by the Philadelphia District Committee at the Franklin Institute on April 12. The evening session at which J. O. Almen, Head Mechanical Engineer, Research Labs., General Motors Corp., Detroit, spoke on the Effect of Residual Stresses on the Fatigue Strength of Structural Materials, was particularly enlivened by discussion. C. H. Gibbons, Application Engineer, Baldwin-Southwark Div., The Baldwin Locomotive Works, described the SR-4 strain gages and demonstrated strain measuring equipment which has been developed. H. R. Gordon, Senior Aeronautical Engineer, Naval Experimental Station, Philadelphia, discussed Structural Trends Dictated by High Speed. It is hoped to publish Mr. Gordon's paper in a forthcoming issue of the BULLETIN. Dr. O. J. Horger who was to join Mr. Almen in the evening session could not be present because he had been called out of the country suddenly.

Mr. Gibbons distributed samples of a wire strain gage and described the three essential components, namely, a type of very fine resistance wire, frequently copper-nickel, an adhesive to fasten the wire rigidly to a base which might be a paper base. The gages are so sensitive they will show a deformation of one millionth of an inch per inch. The use of the gages is based upon Lord Kelvin's law that with changes in stress go changes in electrical resistance. These changes are so small that very precise instruments are required, and use is made of the Wheatstone bridge, oscilloscopes, etc., to measure and record the electrical changes in the strain gages.

The gages can be scanned separately or they may be arranged in multiples up to several hundred which can be scanned automatically.

In his paper, Mr. Gordon referred to the problems of buffet, flutter, and vibration, with which every aircraft designer is concerned. A most important thing to keep in mind when discussing these problems is the structural weight which must be kept low. In fighting aircraft, after additions, such as armor, guns, auxiliary gas tanks, etc., the weight may be increased as much as 25 per cent. He discussed at length some of the new higher strength aluminum alloys, comparing them with the standard 24 ST; he then considered certain sandwich possibilities where the core might be balsa or some other type of wood, and the covering aluminum; he also discussed experimental work done with certain magnesium alloys. The use of certain plastics was noted, but in the final analysis, he pointed out that the more or less conventional higher type aluminum material, either in sheet form or extruded, seemed to provide the best properties to resist strains on the aircraft.

In introducing Mr. Almen, Technical Chairman F. G. Tatnall, who planned the program for the meeting, mentioned he would present some revolutionary ideas in connection with design. The material presented was not only very thought-provoking, but the manner of presentation through exhibits and demonstration added immeasurably to the interest in Mr. Almen's remarks. His talk was notable not only for the subject matter, but for its length. When any technical audience will sit without uneasiness, and without anyone making his exit, through a two hour, ten minute discussion, it is evidence that the subject is of very vital interest.

Perhaps the basic premise of Mr. Almen's comments on residual stresses, and whether they can be used to increase the strength and effectiveness of material, was that failure will not take place in compression, but primarily in tension. Thus he demonstrated two pieces of glass, from the same sheet one of which had been heated and quenched, placing the surface in compression. This would sustain his weight; whereas the other piece could not stand the strain, and fractured instantly. This theory was translated into all kinds of materials, parts, gears, and even to rubber tires. Constantly he reiterated the necessity of careful analysis of all the facts. For example, he cited cases where stress relieving, instead of helping had actually harmed a material. Also several cases where tests had given data that, while clear from the standpoint of test, were erroneous in deciding on design and serviceability of a product.

Whether surface preparation in placing certain parts of structures in compression was obtained by shot peening or nitrating or carburizing would depend upon the particular material, and its shape or related features. But Mr. Almen effectively demonstrated the value of peening in connection with malleable and cast iron by showing on a graph the value of normal fatigue endurance limits, and then after peening, the chart had to be unrolled and unrolled to show the increase of many hundredths of per cent in the endurance limit.

It is not possible to present in a concise manner the gist of his remarks, but every materials technologist and engineer should be acquainted with the remarkable results obtained through Mr. Almen's work. Several of his papers have been published, and some are noted here.

Dimensional Value of Lubricants in Gear Design (*SAE Journal, Transactions*, Vol. 50, No. 9).

Facts and Fallacies of Stress Determination (*SAE Journal, Transactions*, Vol. 50, No. 2).

Durability of Automobile Gears, Part I, Spiral-Bevel Gears, Part 2, Transmission Gears (*Automotive Industries*, September 25, 1937, and October 9, 1937).

On the Strength of Highly Stressed, Dynamically Loaded Bolts and Studs (*SAE Journal, Transactions*, Vol. 52, No. 4).

J. O. Almen

Shot Blasting to Increase Fatigue Resistance (*SAE Journal, Transactions*, Vol. 51, No. 7).

Peened Surfaces Improve Endurance of Machine Parts (*Metal Progress*, Feb., May, Aug., Sept., 1943).

The following is an excerpt from one of the papers noted:

"The study of fatigue of materials is properly the joint duty of the metallurgical, engineering, and production departments. Unless all of these departments have an understanding of fatigue phenomena and the factors that promote fatigue, they cannot recognize their individual responsibilities for the product they manufacture. There is no definite line of demarcation between mechanical and metallurgical factors that contribute to fatigue, and there must, therefore, be very close cooperation between the metallurgist and the engineering fatigue specialist, if such there is, or the metallurgist must possess the qualifications of the metallurgist, designer, and machinist. This overlapping of responsibility is not sufficiently understood in industry and hence the engineers are constantly demanding new metallurgical miracles, instead of correcting their own faults. It would be very helpful if the metallurgists would be less willing to look for metallurgical causes of fatigue and insist that equally competent examination for mechanical causes be made. Until this is done, we cannot hope to make full use of our engineering materials."

L. E. Ekholm, Alan Wood Iron and Steel Co., Chairman of the Philadelphia District Committee presided, with Mr. Tatnall acting as Technical Chairman. There was discussion presented by a number of leading authorities present, including C. A. Adams, H. Styri, J. M. Lessells, W. Johnson, and R. R. Moore.

ASA Conference of Staff Executives

BASED upon the recommendations of a special Exploratory Committee of Staff Executives, it is proposed to establish a Conference of Staff Executives of Member Bodies and Associate Members of the American Standards Association, having the following purposes in mind:

(*a*) Promoting better understanding among association executives of the American standardization movement,

(*b*) Exchanging information among Member Bodies and Associate Members regarding their respective standardization activities, policies, and procedures,

(*c*) Promoting better understanding among association executives of the purposes, organization, policies, and procedures of the American Standards Association,

(*d*) Providing a means for such staff executives to discuss matters of mutual interest to ASA and its Member Bodies and Associate Member, and

(*e*) Making available to the Board and officers of the Association a group whose advice on request might be helpful to the advancement of the ASA.

This Conference will be authorized to conduct forums for discussion of standardization problems and activities of broad national significance. It is felt these forums will provide a means for promoting the standardization movement among the member bodies and other organizations potentially interested in standardization of furthering the desirable cooperative relations between these bodies and the ASA, and of promoting acquaintance and collaboration between executives of these bodies and the ASA.

In order to implement the formation of this Conference and to carry on its activities, a Conference Executive Committee of nine members has been appointed under the chairmanship of C. L. Warwick, Secretary-Treasurer, A.S.T.M., the complete personnel of this Executive Committee being as follows:

C. L. Warwick, Secretary-Treasurer, American Society for Testing Materials, *Chairman*,
Miss Irene Blunt, Secretary, National Federation of Textiles,
Percy Bugbee, General Manager, National Fire Protection Association,
W. J. Donald, Managing Director, National Electrical Manufacturers Association,
C. B. LePage, Assistant Secretary, American Society of Mechanical Engineers,
Herman Lind, President, American Institute of Bolt, Nut and Rivet Manufacturers,
Harry B. Lindsay, Secretary-Treasurer, Grinding Wheel Manufacturers Association,
T. E. Veltfort, Manager, Copper & Brass Research Association, and
John A. C. Warner, Secretary and General Manager, Society of Automotive Engineers.

Among the subjects that have been suggested for discussion are:

1. The legal aspects of standardization,
2. The relationships between industry and Government in standardization work,
3. The practical significance and potentialities of industrial standardization,
4. Simplified practice recommendations and type standardization, and
5. What can the ASA do to promote and strengthen the standardization work of its Member Bodies?

Such discussions should prove to be very helpful.

Chilean Institute of Technology and Standards

A NATIONAL Research Institute of Technology and Standards has been organized in Chile to deal with technical and standards problems. The Institute is to study and coordinate industrial and scientific problems relating to national production. It will investigate raw materials, develop plants for new industries, investigate technical problems for the government and private industry, develop technical standards, sponsor promotion of knowledge through publications, lectures, etc., and act as a research laboratory. The sponsors of the new Institute are the University of Chile, Chilean Institute of Mining Engineers, Chile Engineers' Association, and the Corporation for Development Production. A number of Chilean organizations, both government and industrial, will be members of the new Institute. Representatives of these groups plus officers of the University comprise the governing Council. The Director of the Institute is Francis Mardones whose headquarters are in Santiago, Chile. It is of interest to note that among the several A.S.T.M. members in Chile, the Laboratory for Testing Materials, University of Chile, has been affiliated with A.S.T.M. since 1917. The present representative is Edmundo Thomas, Manager Engineer.

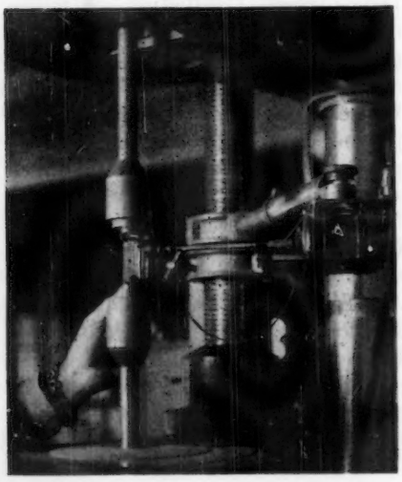
Correction in Mercurous Nitrate Test for Copper Alloys

ATTENTION is called to a correction that should be made in the Tentative Method of Mercurous Nitrate Test for Copper and Copper Alloys (B 154 – 41 T). The method at present calls for the use of "10 ml." of nitric acid. This should be "13 ml." and applies to line 4 of Section 3 (*a*), line 4 of Section 3 (*b*) (Procedure A), line 7 of Section 3 (*b*) (Procedure B), and line 8 of Section 3 (*c*).

These changes should be noted on page 1652 of the 1944 Book of A.S.T.M. Standards, Part I, and on page 302 of the compilation "A.S.T.M. Standards on Copper and Copper Alloys," December, 1944.

Production and Design for Powder Metal Parts

IN THE January, 1945, A.I.M.E. *Metals Technology* is published a Symposium on Production and Design Limitations and Possibilities for Powder Metallurgy Parts. The twelve papers comprising the 96-page symposium are by leading authorities including a number of men active in A.S.T.M. Committee B-9 on Metal Powders and Metal Powder Products. Dr. F. N. Rhines in his foreword points out that "Open discussion either through literature or technical assembly serves a highly useful purpose in furthering a general understanding of applications and developments in a particular field. The research man to a large extent relies for guidance upon the needs expressed by the engineer. Furthermore, interchange of ideas not only increases some knowledge, but stimulates creative thought." The symposium in addition to the papers has a considerable amount of interesting discussion. Copies of this issue of *Metals Technology* can be obtained from A.I.M.E. Headquarters, 29 West 39th St., New York 18, N. Y., at $1.25.



Tensile Test with Automatic Stress-Strain Recording Device. Photograph courtesy Research Laboratory, Midvale Co. From a short article by F. B. Foley in the Midvale Safety Bulletin.

New Instrument Society Announced

A NATIONAL organization known as "The Instrument Society of America" was instituted in Pittsburgh in April by delegates from some 15 local measurement and control instrument groups. The purpose of the society will be to advance the arts and sciences that are connected with the theory, design, manufacture, and use of instruments. The society is nonprofessional, and offers membership to any person, firm, or institution interested in the objectives of the society. Pro-tem officers were elected as follows: President, A. F. Sperry (Chicago); Vice-President, C. F. Kayan (N. Y.); Treasurer, C. E. Fry (Pittsburgh); Secretary, Richard Rimbach (Pittsburgh). Various committees were appointed to proceed with the organization work, and preparation of constitution and by-laws. The office of the Secretary is the temporary office of the society and is located at 1117 Wolfendale St., Pittsburgh 12, Pa.

Society Appointments

Announcement is made of the following Society appointments:

J. L. MINER, Atlas Lumnite Cement Co., as a member-at-large of Committee E-8 on Nomenclature and Definitions, succeeding Cloyd M. Chapman, deceased.

N. L. MOCHEL, Westinghouse Electric and Manufacturing Co., and chairman of Committee A-1 on Steel on the S.A.E. Iron and Steel Division, and ROBERT J. PAINTER, Assistant to the Secretary, A.S.T.M., and Secretary, Committee A-1 on Steel, as alternate.

J. R. BONNAR, General Dyestuff Corp., in place of K. H. Barnard, Pacific Mills, on the A.S.A. Sectional Committee on Fastness of Colored Textiles.

V. T. MALCOLM, The Chapman Valve Manufacturing Co., on the Joint Research Committee of A.S.T.M. and A.S.M.E. on Effect of Temperature on the Properties of Metals.

H. H. MORGAN, Robert W. Hunt Co., and R. E. HESS, Assistant Secretary, A.S.T.M., reappointed as representative and alternate, respectively, on the A.S.A. Mechanical Standards Committee.

A. G. ASHCROFT, Alexander Smith and Sons Carpet Co., and R. E. HESS, Assistant Secretary, A.S.T.M., reappointed as representative and alternate, respectively, on the A.S.A. Advisory Committee on Ultimate Consumer Goods.

H. H. LESTER, Watertown Arsenal, chairman of Committee E-7, as A.S.T.M. representative on the War Committee on Safety Code for the Industrial Use of X-rays.

L. S. REID, Metropolitan Life Insurance Co., chairman of Committee D-6, as A.S.T.M. representative on the Advisory Committee on TAPPI Testing Division.

R. W. CRUM, National Research Council, as A.S.T.M. representative on the American Documentation Institute.

Catalogs and Literature Received

CARL SCHLEICHER & SCHUELL CO., 116–118 West 14th St., New York 11, N. Y. Bulletin No. 67 covering S & S American Analytical Filter Papers for use in Chemical Laboratories. Covers relative values of retention, then details various series, such as ash-free, ash-low, hardened, tear-proof, etc. Page size 6½ by 9½ in., 24 pages, illustrated.

TABER INSTRUMENT CORP., North Tonawanda, N. Y. This twelve-page splendidly illustrated folder covers the Taber Abraser test and gives full details of the testing set, and the several accessories including the shear hardness attachment. This abraser is designed to duplicate in measurable terms the rubbing abrasion encountered in actual service. Page size 8½ by 11 in.

HARRY W. DIETERT CO., 9330 Roselawn Ave., Detroit 4, Mich. One-page leaflet describing the Glotemp Combustion Furnace used for steel laboratories running carbon analysis. Illustrated.

BURRELL TECHNICAL SUPPLY CO., 1936–42 Fifth Ave., Pittsburgh 19, Pa. Catalog 80—"Burrell Gas Analysis Apparatus and Burrell Manual for Gas Analysts." The first part describes laboratory models, portable models, gas purity testers, replacement parts, reagents, etc. The second section (Burrell Manual) gives characteristics of some commercial gases, principles of analysis, assembling the apparatus, preparing it for use, analytical procedure, calculations, etc. 96 pages, illustrated.

AMERICAN MACHINE AND METALS, INC., East Moline, Ill. A twelve-page booklet entitled "1944 In Review" briefly describes the major activities of the company during the past year. Mentions various products manufactured.

ENGINEERS SPECIALTIES DIVISION, THE UNIVERSAL ENGRAVING AND COLORPLATE CO., INC., Buffalo, N. Y. A booklet, "Detail (Graph-Type) Engineers Glass," describing two types, the new Grid Comparator Charts, etc.

PICKER X-RAY CORP., 300 Fourth Ave., New York, N. Y. A profusely illustrated twelve-page folder entitled "5 to 50 KVP Industrial X-ray Units." Describes important uses of low-voltage radiography, typical applications of low-voltage radiography, details of Picker 5 to 50 KVP Industrial X-ray Unit—X-ray tube, cap, tube support, transformer, control unit and cabinet.

PRECISION SCIENTIFIC CO., 1750 N. Springfield Ave., Chicago 47, Ill. Catalog 325 entitled "Precision (Freas) Temperature Control Cabinets." This 48-page, 8½ by 11-in. catalog, covers the extensive Precision-Freas line of temperature-control cabinets. Sections of the profusely illustrated catalog are devoted to general specifications, methods of heat transfer, general purpose ovens, cabinets for specific uses, hazard-safe cabinets, incubators, special-built equipment, and dial thermometers. It is of interest to note that Dr. Freas designed and built his first constant-temperature cabinet at the University of Chicago in 1907.

Synopses of 1945 Reports and Papers

[These Reports and Papers were listed either on the preprint request blank forwarded to the members early in May or on the blank included on p. 40 of the May, 1945, ASTM BULLETIN, or will be included in later issues of the ASTM BULLETIN. See p. 5 of this issue for a more complete explanation.]

Annual Report of the Executive Committee. C. L. Warwick, Secretary-Treasurer.

A general report on Society activities, including a review of membership, publications, finances, new headquarters, and administrative matters dealing with committee activities and the Society's relations with various other organizations. Reference is made to important new developments growing out of critical examination of Society problems by the Special Study Committee, including extension of work in the standardization of tests and specifications for ultimate consumer goods; the study, development, and standardization of methods of test of simple or composite materials in actual or simulated service conditions; changes in methods of publication of technical papers; and changes in the administration of Society affairs, involving among other things the establishment of a Board of Directors as the governing body of the Society, requiring amendment of the charter and by-laws of the Society.

Report of Committee E-1 on Methods of Testing. W. H. Fulweiler, Chairman.

This progress report reviews briefly the activities of the committee during the past year.

Report of Committee E-10 on Standards. H. S. Vassar, Chairman.

The numerous new and revised tentatives and tentative revisions of existing standards accepted by Committee E-10 during the year are listed. The actions taken by the committee with respect to emergency standards and emergency alternate provisions are also recorded. Steps are being taken to determine the desirability of the Society undertaking standardization work in the field of leather and asbestos-cement products.

Metals

Reports:

Report of Committee A-1 on Steel. N. L. Mochel, Chairman.

Report of Committee A-3 on Cast Iron. J. T. MacKenzie, Chairman.

Report of Committee A-5 on Corrosion of Iron and Steel. C. D. Hocker, Chairman.

Data are given with respect to the corrosion studies at various locations including a report of inspections at the Annapolis locations of the No. 22 gage copper-bearing and noncopper-bearing corrugated black sheets which have been exposed since 1916. Also included is a detailed report containing results of atmospheric corrosion tests on wire and wire products after exposure for about 8 yr. at eleven test locations.

Report of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys. Jerome Strauss, Chairman.

The tentative specifications for nickel and nickel-base alloy clad steel plate are recommended for adoption as standard. Revisions in the standard specifications for chromium-nickel alloy-steel castings are under consideration. It is reported that a second round-robin tension testing program dealing with the effect of specimen preparation has been completed and that the program on atmospheric corrosion tests of stainless steels is being continued.

Report of Committee B-1 on Copper and Copper-Alloy Wires for Electrical Conductors. J. H. Foote, Chairman.

The tentative specifications for rope-lay-stranded copper conductors, having bunch-stranded and concentric-stranded members, and for bunch-stranded copper conductors for electrical conductors are recommended for adoption as standard as revised. Revisions in the standard specifications for tinned soft or annealed copper wire for electrical purposes, for soft rectangular and square copper wire for electrical conductors, for concentric-lay-stranded copper conductors, hard, medium-hard, or soft, and for soft or annealed copper wire are recommended for immediate adoption.

Report of Committee B-2 on Non-Ferrous Metals and Alloys. E. E. Thum, Chairman.

This progress report reviews briefly the activities of the committee during the year.

Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys. H. S. Rawdon, Chairman.

This report reviews briefly the activities of the committee during the year and mentions various projects which are under way including a study of the effect of settling of fog on the rate of corrosion of selected materials and plans for galvanic corrosion tests on atmospheric exposure of two magnesium alloys.

Report of Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys. Dean Harvey, Chairman.

This progress report in covering the activities of the various subcommittees refers to work which is under way looking toward the preparation of specifications for chromium-nickel-iron alloy castings (35 per cent nickel, 15 per cent chromium, balance iron) for high-temperature service. Because of the difficulty of accurately measuring the diameter of fine wires, a new method has been prepared, which is still in draft form, in which a 200-mm. length of wire is weighed and the diameter calculated. It is intended to apply to wires of 0.002 in. in diameter or less. A method for determining the strength of welds in wires used for leads is under consideration. The 1945 Supplement to the Bibliography and Abstracts on Electrical Contacts prepared by the committee has recently become available.

Report of Committee B-5 on Copper and Copper Alloys, Cast and Wrought. G. H. Harnden, Chairman.

Five proposed tentative specifications are included as follows: specifications for beryllium-copper alloy strip, special grade, beryllium-copper alloy strip, beryllium-copper alloy rod and bar, beryllium-copper alloy wire, and copper-silicon and copper-silicon-zinc alloy castings. Revisions are recommended in eighteen of the tentative specifications and eleven of the standard specifications under the jurisdiction of the committee. The revised classification of cast copper-base alloys is also appended. The tentative specifications for copper-base alloy forging rods, bars, and shapes, for brass wire, and for copper-alloy condenser tube plates, as well as the tentative test for expansion (pin test) of copper and copper-alloy tubing and method of mercurous nitrate test for copper and copper alloys are recommended for adoption as standard.

Report of Committee B-6 on Die-Cast Metals and Alloys. J. R. Townsend, Chairman.

This progress report reviews briefly the activities of the committee during the year.

Report of Committee B-7 on Light Metals and Alloys, Cast and Wrought. D. L. Colwell, Chairman.

The tentative method of test for dielectric strength of anodized aluminum, the test for sealing of anodically coated aluminum, and the test for weight of coating on anodically coated aluminum are recommended for adoption as standard. Revisions in the specifications for magnesium alloy products are under consideration. The report includes a description of the system designating aluminum alloys adopted by the committee. Results of the exposure tests of anodized samples are appended.

Report of Committee B-8 on Electrodeposited Metallic Coatings. R. J. McKay, Chairman.

Proposed tentative specifications for chromate finishes on zinc are appended as well as a report setting forth the results of inspections to date of electrodeposited lead coatings on steel. The emergency specifications for electrodeposited coatings of lead on steel are recommended for publication as tentative with slight revision. Revisions are also recommended in the tentative specifications for electrodeposited coatings of nickel and chromium on steel, on copper and copper-base alloys, and on zinc and zinc-base alloys, and in the tentative methods of test for local thickness of electrodeposited coatings.

Report of Committee B-9 on Metal Powders and Metal Powder Products. W. A. Reich, Chairman.

Report of Committee E-2 on Spectrographic Analysis. H. V. Churchill, Chairman.

Report of Committee E-3 on Chemical Analysis of Metals. G. E. F. Lundell, Chairman.

Report of Committee E-4 on Metallography. L. L. Wyman, Chairman.

Report of Committee E-7 on Radiographic Testing. H. H. Lester, Chairman.

Report of Joint Research Committee on Effect of Temperature on the Properties of Metals. N. L. Mochel, Chairman.

A brief summary of the progress made during the year in the various research projects sponsored by the joint committee including tests of tubular members subject to internal pressures, relaxation tests, effect of variables on the high-temperature properties of metals, and comparison of short-time test methods.

Report of Joint A.W.S.—A.S.T.M. Committee on Filler Metal. J. H. Deppeler, Chairman.

Records the recent approval by Committee E-10 on Standards of an extensive revision of the tentative specifications for iron and steel arc-welding electrodes including the addition as information of a guide to A.W.S.-A.S.T.M. Classification of Iron and Steel Arc Welding Electrodes. It briefly reviews the work of the committee and consideration being given to other specifications for filler metal of nickel, nickel alloys, copper and copper-alloy electrodes, and stainless steel arc-welding electrodes.

Report of Research Committee on Fatigue of Metals. H. F. Moore, Chairman.

Papers:

***Fracture Testing of Alloy Steels for Aircraft Engine Forgings.** R. D. Haworth, Jr., and A. F. Christian, Wyman-Gordon Co.

An unusual condition of alloy steel forgings, shown by fracture examination and termed "grain coarsening," has attracted considerable interest in recent years among the manufacturers of highly stressed aircraft engine parts. While a small amount of grain coarsening has no harmful effect on physical properties, a larger amount decreases toughness, and hence the condition should be eliminated from aircraft engine members as far as possible.

The appearance of large grains or "facets" on the fractured surface of fully heat treated forgings was generally considered indicative of overheating during the forging operation. However, it has been clearly demonstrated that this condition can be produced in certain heats of steel at normal forging temperatures. Other factors equally as influential as heat sensitivity are (1) the time at temperature and (2) the amount of reduction during the forging operation.

Photographs of fractures after various heat treatments are shown and a complete set of fracture test standards are presented. Operation of the test in production is described as well as the results which have already been achieved. A study of the present state of knowledge concerning the cause and mechanism of grain coarsening is also submitted.

***The Effect of Iron Content of Cupro-Nickel on Its Corrosion Resistance in "Sea Water."** A. W. Tracy and R. L. Hungerford, The American Brass Co.

Data are given on a laboratory investigation concerning the effect of iron additions to cupro-nickels on the corrosion resistance of the alloys exposed to "sea water" in motion. The "sea water" was a 3 per cent solution of sea salt. Sheet metal specimens were tested by attaching to fiber disks which were rotated in the test solution and tube specimens were placed in an experimental condenser.

The extent of corrosion is determined on sheet metal specimens by measuring losses in thickness by means of sharp-pointed micrometers. Corrosion of tube specimens is judged from visual examinations.

The tests show quite conclusively the effect of iron content in improving the corrosion resistance of cupro-nickels in sea water and indicate that as the nickel content of the alloy is decreased, increasing amounts of iron are required for optimum corrosion resistance.

The Effect of Combined Stresses on the Mechanical Properties of Steels at Temperatures down to −188 C. D. J. McAdam, Jr., G. W. Geil, and R. W. Mebs, National Bureau of Standards.

From results of tension tests of notched cylindrical specimens at temperatures down to −188 C., information has been obtained about the influence of notch angle, root radius, and temperature on strength and ductility. Chief attention is given to carbon steels in annealed and in cold worked conditions. Diagrams have been developed to show the influence of combined stresses, stress concentration and temperature on yield stress, ultimate stress, technical cohesive limit and ductility. The diagrams show the combined influence of temperature, triaxial tension, and stress concentration in producing brittleness.

The Effect of Overstress in Fatigue on the Endurance Life of Steel. J. B. Kommers, University of Wisconsin.

The purpose of the experiments was to determine the effect of overstress on the endurance life rather than on the endurance limit of steel. Specimens were stressed for a limited number of cycles at one stress level and were then tested to failure at either a higher or lower stress level. If the endurance life is decreased a certain percentage at one stress level, does this mean that the endurance life has been decreased the same percentage at a subsequent higher or lower level? In general, it was found that this is not the case.

When the initial overstress is high and the final overstress lower, the damage to endurance life is, in general, greater at the final than at the initial stress. When the initial stress is low and the final stress higher, the damage to endurance life is, in general, less at the final than at the initial stress.

The Spectrochemical Analysis of Steel with a Direct Reading Instrument. M. F. Hasler and H. W. Dietert, Harry. W. Dietert Co.

A set of instruments termed the "Quantometer" is described which allows direct-reading, spectro-chemical analysis of steels and other alloys. Three instruments are involved—a special twelve-receiver, grating spectrometer; a recording console; and a source unit. Extended tests show that the quantometer is equal or superior in accuracy to the conventional spectrographic installation due to the elimination of photographic recording with its attendent variables. Results are presented showing the successful application of these instruments to the high-speed analysis of manganese, chromium, nickel, silicon, copper, molybdenum, and vanadium in low-alloy steels.

A Theory of the Mechanism of Rusting of Low Alloy Steels in the Atmosphere. Harry R. Copson, The International Nickel Co., Inc.

Analyses of rust samples are presented, along with an examination of weather data and some weight losses. Copper and nickel in steel render sulfate corrosion products more insoluble by forming complex basic sulfates. On mild steel the sulfates in the rust are relatively soluble and promote corrosion but are washed away by rain. On alloy steels the sulfates are less soluble so that corrosion is slower, but less sulfate is washed away and more accumulates in the rust. The percentage of sulfates in the rust increases as weight loss decreases. Severe corrosion of certain edges was due to the wash of rain.

Structural Charges in Carbon and Molybdenum Steels during Prolonged Heating at 900–1100 F., as Affected by Deoxidation Practice. George V. Smith, United States Steel Corp.

Annealed and normalized samples of 0.1 per cent carbon and of 0.1–0.2 per cent carbon–0.5 per cent molybdenum steels of different deoxidation practice were heated at 900, 1000, and 1100 F. for periods up to 5000 hr. and then subjected to hardness tests and to metallographic examination for microstructural changes.

A Statistical Analysis of the Total Immersion Tests of A.S.T.M. Subcommittee V, Committee A-5. V. V. Kendall, National Tube Co.

This paper is a review of the work of Subcommittee V of Committee A-5 on Corrosion of Iron and Steel, since its organization. It consists primarily of a multiple correlation study of the total immersion test data collected by Subcommittee V to determine the individual and joint effects of carbon, manganese, phosphorus, sulfur, silicon, and copper on the corrodability of steel.

A Sulfur Print Method for the Study of Crack Growth in the Corrosion Fatigue of Metals. R. C. Brumfield, California Institute of Technology.

The novel design features of a rotating-beam type corrosion-fatigue machine and the technique for damaging specimens is briefly described. A method for evaluation of corrosion fatigue damage is given. This method is based on a procedure for making sulfur prints (contact prints) of the crack patterns on the cylindrical surfaces of a damaged specimen turned down to successive radial depths. These contact prints are analyzed, the crack profiles (polar diagrams) drawn, and the depths of crack penetration measured. By using several specimens, the rate of crack growth can be determined, provided the "experimental scatter" is not excessive. The entire method is described in detail and can be duplicated with the most elementary laboratory facilities.

Practical Electric Resistance Strain Gage Procedures for Structural Tests on Ships. W. V. Bassett, Bethlehem Steel Co.

This paper is preprinted in this issue of the Bulletin.

Single-Strip Compression Test for Sheet Materials. Harry LaTour and Don S. Wolford, The American Rolling Mill Co.

This paper presents a new jig for testing sheet materials in compression using a flat single-strip specimen. The jig prevents lateral buckling of the specimen by providing continuous support in the form of flat guides. Both ends of the specimen extend beyond the jig body an amount exceeding the total deformation during the test. Consideration is given to the length of these extensions so that compression properties can be obtained on materials having yield strengths of 180,000 psi. and even greater.

Results of single-strip tests on steels having thicknesses between 0.010 and 0.050 in. and yield strengths ranging from 50,000 to 180,000 psi. are given for the new jig.

Tests made by the authors show that compression stress-strain data can be obtained on sheet materials using a routine procedure requiring about the same time and care as a comparable tension test.

Observations on the Appearance Welding of Malleable Castings. H. A. Schwartz, Ira Young, and James Hedberg, National Malleable and Steel Castings Co.

The paper concerns itself only with welding to improve the appearance of malleable castings. Such welds must be reasonably ductile and soft enough not to interfere with machining at rates normally used for malleable castings. The use of white cast-iron welding rod and a subsequent complete malleable anneal is time consuming and greatly retards the output of an annealing department.

Welds made with soft steel and with monel metal followed by rather short tempering heat treatments are described; the latter in particular meeting the requirements satisfactorily.

Since the literature seems barren of data regarding the metallography and hardness distribution of welds, this aspect of the problem is elaborated.

The authors had the benefit of advice and discussion on the part of J. J. Kanter and J. H. Lansing, who with the senior author, constitute a temporary Subcommittee on welding of Committee A-7

* These papers were preprinted and distributed through the request blank inserted in A.S.T.M. BULLETIN, No. 133, March, 1945, p. 40.

The Corrosion-Fatigue Properties of Some Hard Lead Alloys in H_2SO_4. David J. Mack, The University of Tennessee.

The fatigue properties of pure lead, tellurium lead, 1 per cent antimonial lead, and commercial storage battery lead were determined on a rotating beam machine of the cantilever type at 1785 rpm. The endurance limits of these four materials were determined: (*a*) in air, the specimens being coated with vaseline; (*b*) in 38 per cent H_2SO_4, the acid being applied to the specimens by dripping; and (*c*) in air after the specimen had been previously corroded in H_2SO_4 while stress free. The endurance limits obtained in (*a*) checked many of those already reported in the literature, all tested at high speed. From the results obtained it was concluded that the corrosion-fatigue resistance of these alloys in H_2SO_4 is a running balance between fatigue strength and corrosion resistance. There was good correlation between the results in (*a*) and (*c*), but not with (*b*). This shows that if the corrosion and cyclic stress occur simultaneously damage is to be expected.

The mechanism of corrosion-fatigue action in lead and lead alloys in H_2SO_4 was examined. It is believed that the $PbSO_4$ film is opened up over the underlying grain boundaries by elastic deformation of the grains and by the tendency of the lead to recrystallize. This allows the acid to attack the grain boundary creating a notch. Once the notch has started, the corrosion-fatigue crack is propagated intergranularly by notch action, it being shown that lead is extremely susceptible to notch action at the speed studied. It is felt that the "breathing" action in the crack during cyclic stressing probably also contributes to the crack propagation but in a minor way. Experimental evidence is offered in support of these proposals.

The Calculation of Electrical Contacts Under Ideal Conditions. Erle I. Shobert, II, Stackpole Carbon Co.

A method is derived for calculating the current rating of electrical contacts under ideal conditions, which involves the contact forces, hardness, resistivity, heat conductivity, and the chemical and metallurgical properties of the materials. Based on experimental data taken by several companies, calculations are shown to be applicable to some fields of contact operation and not sufficiently complete for others. The use of proper safety factors which must be chosen for various fields of application is suggested for the use of calculations. Using the formulas which are derived based on previous work on contacts and using the ideas set forward in this paper concerning the factors which limit contact temperatures, it is possible to set an upper limit on the current which may be carried by any particular set of contacts under a given pressure. On the other hand, pressure required on a set of contacts to handle a certain current may be calculated on the same basis.

Cast to Size Impact Specimens for Aluminum Sand Casting Alloys. R. A. Quadt, American Smelting and Refining Co.

The production of satisfactory cast to size Charpy impact specimens in sand by means of a matchplate is described. A design permitting the production of both unnotched and V-notched specimens in a single casting containing a total of 26 specimens was developed. A commercial aluminum casting alloy containing 4 per cent copper and 1 per cent silicon was used in the investigation. Tension properties, cast to size impact properties, and impact properties of comparable types of machined specimens in various heat-treated conditions are reported.

It was concluded that multiple Charpy impact specimens could be cast to size in sand which would give consistent values for aluminum casting alloys. A marked skin effect was noted for the unnotched specimens of the alloy which doubled the toughness as compared to similar machined specimens. Notched specimens gave equivalent impact properties for test pieces produced either by casting or by machining.

Cement, Concrete, Lime, Refractories, Masonary Materials

Reports:

Report of Committee C-1 on Cement. P. H. Bates, Chairman.

No formal recommendations are being made at this time, but proposed specifications for portland-blast-furnace slag cement and a proposed method of test for fineness of portland cement by the Blaine air-permeability apparatus are appended as information. Also included as information are proposed revisions to be recommended in the specifications for portland cement and in the specifications for air-entraining portland cement, as well as in the methods of sampling hydraulic cement. A résumé is given of the activities of the committee including a cooperative study to determine the dependability of the mortar bar expansion test and the degree of reproducibility of results and a series of cooperative tests to determine the day-to-day variations in fineness values determined by the turbidimeter and the air-permeability methods. Included are extensive reports and a tabulation of data on comparative short-time tests for sulfate resistance of 121 commercial cements.

Report of Committee C-4 on Clay Pipe. J. C. Riedel, Chairman.

This brief progress report refers to the new tentative specifications for extra strength clay pipe and for standard strength clay sewer pipe, accepted by Committee E-10 during the year, which had been prepared by Committee C-4 in an effort to coordinate all the specifications for standard strength and extra strength clay pipe which are now available, and are considered a definite step toward obtaining national uniform standards for clay pipe. The standard recommended practice for laying sewer pipe is being reviewed looking toward possible revision.

Report of Committee C-5 on Fire Tests of Materials and Construction. S. H. Ingberg, Chairman.

Reference is made to consideration being given to revising the proposed methods of fire tests of window assemblies which it is expected will be submitted to Committee E-10 during the year for publication as tentative. It is mentioned that the committee is preparing a method for conducting fire tests of wood using the fire tube apparatus developed by the U. S. Forest Products Laboratory. A number of fire tests of roof constructions are being conducted looking toward revision of the standard methods of fire tests of building construction and materials. Attention is also being given to the development of a method of conducting fire tests of ceiling constructions as distinct from floor constructions.

Report of Committee C-7 on Lime. W. C. Voss, Chairman.

Report of Committee C-8 on Refractories. J. D. Sullivan, Chairman.

Tests for bonding strength and refractoriness of air-setting refractory mortars and tests for thermal conductivity of refractories, insulating fire brick, and fireclay refractories, as well as specifications for air-setting refractory mortars, recently accepted by Committee E-10 on Standards for publication as tentative as recommended by Committee C-8, are appended to the report. The panel test for resistance to thermal and structural spalling of fireclay plastic refractories and the test for workability index of fireclay plastic refractories are recommended for adoption as standard. Tentative revisions applying to the standard methods of panel test for resistance to thermal and structural spalling of refractory brick, high heat duty fireclay brick, and super duty fireclay brick are also recommended for adoption as standard.

Report of Committee C-12 on Mortars for Unit Masonry. Theodore I. Coe, Chairman.

Reference is made to consideration being given to the preparation of specifications for mortars for unit masonry and to revising the tentative specifications for mortar for reinforced brick masonry. Research has been conducted on methods of test for efflorescence of mortars, particularly through the use of efflorwicks (standard clay units).

Report of Committee C-14 on Glass and Glass Products. Louis Navias, Chairman.

Report of Committee C-15 on Manufactured Masonry Units. D. E. Parsons, Chairman.

As indicated in this brief report, much of the research and other activities of the committee have been somewhat curtailed due to wartime conditions. In the light of experience, revisions are recommended in the tentative specifications for vitrified clay filter block for trickling filters.

Report of Committee C-16 on Thermal Insulating Materials. E. T. Cope, Chairman.

The tentative tests for compressive strength of preformed block type thermal insulation, for thermal conductivity of materials by means of the guarded hot plate, and for covering capacity and volume change upon drying of thermal insulating cement are recommended for adoption as standard. A résumé is given of the activities of the various subcommittees. Reports studies being made of method for determining the adhesion to steel of insulating cement.

Papers

***The Testing of Portland Cements Containing Interground Vinsol Resin.** Raymond L. Blaine, Jason C. Yates, and John R. Dwyer, National Bureau of Standards.

Tests were made on 64 commercially manufactured air-entraining portland cements containing interground Vinsol resin to obtain information on methods of testing. Data are presented in tables and figures on the fineness and water requirements of the cements, the amount of air entrained in various pastes, mortars, and concrete, and the tensile and compressive strengths of test mortar specimens at 3, 7, and 28 days. The tests reported furnish information relating to some of the recent changes in methods of test and specification requirements of air-entraining cements.

***Properties of Highly Hydrated Dolomitic Masonry Limes and Certain of Their Cement-Lime Mortars.** G. J. Fink and Emil Trattner, National Lime Assn.

Presents the results of tests of the six commercially available masonry limes of a new type, the highly hydrated dolomitic limes. Data are presented on the chemical and physical properties of the limes, on the physical properties of mixtures in the proportion of 1 bag of portland cement to 2 bags of lime tested as masonry cements, and on 1:2:9 mortars prepared from the limes. In order to simulate more nearly the conditions of job use, additional 1:2:9 mortars were also tested 30 min. after the initial mixing and after the mortars had been subjected to suction for 1 min. All the limes contained small percentages of unhydrated oxides and showed low expansions in the autoclave; all had high plasticities and high water retentivities. All the mortars made with these limes exhibited good workability and unusually high water retentivity.

A Method of Particle Size Determination of Soils, Cements, etc., by Means of a Chainomatic Specific Gravity Balance. Eugene V. Barrett, Ministry of Public Works of Venezuela.

The hydrometer method of particle size determination of soils and the Wagner Turbidimeter method of determining the specific surface of cement are briefly discussed together with the assumptions and inconveniences of these methods.

A method is described which eliminates the computations and corrections of the hydrometer method and which permits the determination of the percentage of particles finer than 0.0015 mm. to be made in 1 hr. and 20 min. instead of the 24 hr. required by the hydrometer method.

A variation of this method permits the determination of the specific surface of cement without calibration against standard samples.

Stress Conditions for the Failure of Saturated Concrete and Rock. Karl Terzaghi, Harvard University.

This article deals with the effect of pore water pressure on the strength of concrete and rock. An analysis of the results of triaxial compression tests on jacketed specimens and on unjacketed specimens leads to the conclusion that the test results can be explained only by assuming that the individual constituents of unjacketed specimens are almost completely surrounded by the permeating liquid. The decrease of the total area of contact between solid and liquid due to low or moderate confining pressures is unimportant.

The Effect of Repeated Loading on the Bond Strength of Concrete. C. W. Muhlenbruch, Carnegie Institute of Technology.

A repeated loading machine which accommodates six pull-out type specimens to which load is applied through levers at a rate of 52,000 repetitions per 24 hr., is described. Rectangular specimens varying from 5 to 10 in. in length and using a $^3/_8$-in. round reinforcing bar were subjected to as many as 5,000,000 cycles of load. It has been found that, as the number of repetitions of loading increase, the static pull-out strength decreases. The ratio of the static pull-out strength after 5,000,000 cycles, to the static pull-out strength of pilot specimens not subjected to repeated loading, was found to be about 50 per cent for specimens 5 in. long and subjected to a load equal to approximately 50 per cent of the static pull-out load. When the load applied to the specimen was reduced to 37 per cent, this ratio decreased to 13 per cent. Values are also reported for the other embedment lengths. Early investigational work of the fatigue strength of both plain and reinforced concrete is briefly summarized in the paper and an extensive bibliography is given.

Equations for Computing Elastic Constants from Flexural and Torsional Resonant Frequencies of Vibration of Prisms and Cylinders. Gerald Pickett, Portland Cement Assn.

The differential equations that have been used for flexural vibration of prisms are examined. It is shown that correction terms that have been proposed in recent papers for the effects of lateral inertia are in error.

Goens's solution of Timoshenko's differential equation is found to be in good agreement with more rigorous solutions from the mathematical theory of elasticity if the shear constant K′ is given the proper value. The proper value depends on Poisson's ratio, being about 5/6 for $\mu = 0$, 8/9 for $\mu = 1/6$, and 0.85 for $\mu = 1/3$.

The resonant frequencies of flexural vibration of thin beams, wide slabs, and cylinders are found by analysis to differ only slightly if the beams, slabs, and cylinders have the same lengths and the same radii of gyration of their cross-sections.

Equations and graphs are given from which Young's modulus can be determined if the weight, dimensions, and resonant frequency of a specimen are known.

Torsional vibration of prisms and cylinders is discussed. Equations are given for Poisson's ratio in terms of the torsional and flexural resonant frequencies of a specimen. Methods for producing and identifying given modes of vibration are suggested.

A Comparison of Absorption and Soundness of Maine Sands. Andrew Adams and Horace A. Pratt, University of Maine.

A series of tests on Maine sands indicates that the result of the magnesium sulfate soundness test (C 88–41 T) may be very closely estimated from the result of the absorption test (C 128–39). Standard A.S.T.M. procedures were followed in obtaining the test results which were based on 62 sands well distributed over the state. The weighted soundness loss may also be predicted from the loss on the 14-mesh fraction alone, as indicated by a high correlation between them.

Test Criterion for an Incombustible Material. S. H. Ingberg and N. P. Setchkin, National Bureau of Standards.

The term "incombustible," while in recognized use as indicating materials that will not ignite or burn, is indefinite in its application unless referenced to a well-defined testing procedure. Among testing methods, that adopted by the British Standards Institution, British Standard 476—1932, appeared to have the most promise of achieving the intended purpose. By this method the sample is heated gradually during the course of $1^1/_2$ hr. in a vertical electrically heated furnace tube up to a temperature of 1382 F. (750 C.), and observations made of occurrence of flame, self-induced glow, or of gases that can be ignited by a pilot flame.

Tests were made with a range of materials by this method, including asbestos insulations with up to about 10 per cent of combustible constituents, acoustical and heat-insulating materials with a larger range in combustible content, and samples of magnesium, aluminum, aluminum alloys, tin, and zinc in a range in particle size. The tests were conducted according to the British Standard and also using the same equipment, by a modified method, involving heating the equipment to the final temperature, 1382 F., before introduction of the sample.

Pure aluminum, duralumin, and aluminum alloyed with silicon and with copper silicon and iron, were indicated as incombustible by both methods, with samples in particle size down to those passing a 200-mesh sieve. However, aluminum paint powder containing 1 to 2 per cent of oil and 0.4 to 0.8 per cent of iron ignited readily by both methods. Magnesium was also ignited by both methods with samples of particle size from that passing a 325-mesh sieve, to a single piece 2 by $1^1/_2$ by $^1/_2$ in. The ignition of tin and zinc was more dependent on particle size and testing method.

Automatic Accelerated Freezing and Thawing Apparatus for Concrete. C. E. Wuerpel and Herbert K. Cook, Corps of Engineers, U. S. Army.

A detailed structural and operational description is given of a newly developed apparatus for automatically and rapidly freezing and thawing $3^1/_2$ by $4^1/_2$ by 16-in. concrete specimens. The temperature of the capacity load of 102 specimens is reversed from 42 F. to 0 F. and from 0 F. to 42 F. in a 2-hr. cycle. Typical results of tests conducted with air-entraining admixtures, aggregates, and water-cement ratios as variables are presented to illustrate the practicability of using the apparatus for acceptance testing based on freezing and thawing.

Effect of Type of Specimen on Apparent Compressive Strength of Concrete. Bryant Mather, Corps of Engineers, U. S. Army.

Miscellaneous

Reports

Report of Committee D-1 on Paint, Varnish, Lacquer, and Related Products. W. T. Pearce, Chairman.

The tentative specifications for oiticica oil, the tentative methods for evaluating the degree of resistance to blistering of organic coatings on metal when subjected to immersion or other tests involving exposure to moisture or liquids, and the tentative methods of analysis of barium sulfate, mica pigment, magnesium silicate pigment, aluminum silicate pigment, and of diatomaceous silica pigment are recommended for adoption as standard without revision. A proposed tentative procedure for operating light and water exposure apparatus (carbon-arc type) for testing paint, varnish, lacquer, and related products, proposed tentative methods of producing films of uniform thickness of organic finishing materials on test panels, and a proposed tentative test for evaluating the degree of resistance of traffic paints to abrasion are appended.

Report of Committee D-2 on Petroleum Products and Lubricants. T. A. Boyd, Chairman.

The method of analysis of petroleum sulfonates, published as information last year, is recommended for publication as tentative. Revisions are recommended for immediate adoption in seven of the standard methods of test under the jurisdiction of the committee. Reference is made to the reorganization of Technical Committee B on Lubricating Oils and to the formation of a new Technical Committee G on Lubricating Grease. A comprehensive report on a proposed method for estimating maximum pour points of lubricating oils containing pour point depressants is appended, together with a proposed method of test included as information. A new proposed method of test for total olefinic and aromatic hydrocarbons in gasoline is also included as information.

Report of Committee D-3 on Gaseous Fuels. A. W. Gauger, Chairman.

This progress report summarizes the activities of the committee during the past year, including the studies now under way on the determination of calorific value, specific gravity and density of gaseous fuels, determination of impurities, and water vapor content of gaseous fuels.

Report of Committee D-4 on Road and Paving Materials. Shreve Clark, Chairman.

This report reviews briefly the activities of the committee during the year.

Report of Committee D-5 on Coal and Coke. A. C. Fieldner, Chairman.

It is recommended that the method of tumbler test for coal be adopted as standard with minor revisions and that a revision of the tolerances between duplicate determinations of volatile matter in the standard methods of laboratory sampling and analysis of coal and coke be published as tentative.

Report of Committee D-6 on Paper and Paper Products. L. S. Reid, Chairman.

Seven new proposed tentative methods are included, as follows: Test for ply adhesion of paper and vulcanized fibre, test for absorption by bibulous papers of water and writing ink, test for degree of wet curl of paper, test for water vapor permeability of sheet materials at elevated temperature and humidity, test for edge tearing strength of paper, and test for tensile breaking strength and wet tensile breaking strength of paper and paper products. Five of the tentative

methods of test under the jurisdiction of the committee are recommended for adoption as standard. A résumé is given of the work before the committee, including consideration of a number of new methods of test.

Report of Committee D-7 on Wood. Hermann von Schrenk, Chairman.

Reference is made to steps which have been taken to broaden the scope of the committee to include activities on a variety of new subjects and materials and to the work of the subcommittees. Presents new proposed tentative methods of determining moisture content of wood, including the use of various types of moisture meters that have been developed during the past several years. Included are revisions in the tentative methods of testing veneer, plywood, and other wood and wood-base materials comprising several new test procedures which supplement the present methods.

Report of Committee D-8 on Bituminous Waterproofing and Roofing Materials. J. S. Miller, Chairman.

Report of Committee D-9 on Electrical Insulating Materials. Myron Park Davis, Chairman.

The proposed methods of test for gas content of insulating oils are recommended for publication as tentative. Revisions are recommended in the tentative specifications for flexible treated sleeving used in electrical insulation, and for natural block mica and mica films suitable for use in fixed mica-dielectric capacitors; also in the tentative methods of testing molded materials and varnished cloths and varnished cloth tapes used in electrical insulation, in the methods of sampling and testing untreated paper used in electrical insulation, the methods of conditioning plastics and electrical insulating materials for testing, and in the test for power factor and dielectric constant of electrical insulating materials. A revised statement concerning the significance of the test for resisitivity of insulating materials is included.

Report of Committee D-10 on Shipping Containers. Edward Dahill, Chairman.

Reference is made to the recent reorganization of the committee and to the revised subcommittee structure. Methods of test for shipping containers in revolving hexagonal drum box testing machines, and a drop test and a compression test for shipping containers have been prepared and, it is expected, will be submitted to the Society for publication as tentative.

Report of Committee D-11 on Rubber and Rubber-Like Materials. Simon Collier, Chairman.

Proposed specifications for natural rubber cups for use in hydraulic actuating cylinders, prepared jointly by the Society of Automotive Engineers and the A.S.T.M., are recommended for publication as tentative as appended to the report. Also attached are a proposed recommended practice for conditioning of rubber and plastic materials for low-temperature testing and proposed methods for identification and determination of synthetic elastomers which are likewise being recommended for publication as tentative. Reference is made to the activities of the committee, including the submittal of a number of recommendations to Committee E-10 during the year resulting in the acceptance of five new tentative specifications and methods of test as well as revisions in a number of the tentatives under the jurisdiction of Committee D-11.

Report of Committee D-12 on Soaps and Other Detergents. F. W. Smither, Vice-Chairman.

A new tentative method of chemical analysis of soaps containing synthetic detergents, revisions in the tentative definitions of terms relating to soaps and other detergents, and a tentative revision of the standard methods of sampling and chemical analysis of soaps and soap products, recently approved by Committee E-10 on Standards on the recommendation of Committee D-12, appear in the report. The tentative specifications for tetrasodium pyrophosphate (anhydrous) and for liquid toilet soap, the tentative methods of test for water-immiscible organic solvents volatile with steam in sulfonated and sulfated oils, and the tentative methods of chemical analysis of industrial metal cleaning compositions are recommended for adoption as standard without revision.

Report of Committee D-13 on Textile Materials. H. J. Ball, Chairman.

Proposed tentative methods of test for rayon cord are under consideration as well as proposed revisions in the standard methods of testing and tolerances for tire cord, woven and on cones, and in the tentative general methods of testing cotton fibers and the tentative methods of quantitative analysis of textiles.

Report of Committee D-14 on Adhesives. T. R. Truax, Temporary Chairman.

This first report of the recently organized committee on adhesives gives information concerning its scope of activities and subcommittee structure. While no proposed specifications or methods of test are being presented at this time, considerable progress has been made in reviewing and compiling existing information and in developing, perfecting, and checking test methods.

The committee is planning to sponsor a symposium on adhesives which will be concerned with the methods of testing adhesives, the need for the preparation of specifications, their character and scope, and what has been done and what is planned for the future.

Report of Committee D-16 on Industrial Aromatic Hydrocarbons. J. M. Weiss, Chairman.

Twelve new proposed tentative specifications for solvents are included, as follows: Specifications for nitration grade benzene, toluene, and xylene; industrial grade benzene, toluene, and xylene; industrial 90 benzene; 5 degree and 10 degree xylene; refined, crude light, and crude heavy solvent naphtha. Methods of test for determining specific gravity, color, and hydrogen sulfide and sulfur dioxide content; distillation; acid wash and acidity of benzene, toluene, xylenes, and similar industrial aromatic hydrocarbons; solidifying point of benzene; paraffins; and a copper corrosion test are also recommended for publication as tentative. Appended to the report are the results of cooperative distillation tests using the method being recommended for publication as tentative in comparison with two alternative methods. Also appended is a report of a special committee on aromatic petroleum solvents.

Report of Committee D-17 on Naval Stores. V. E. Grotlisch, Chairman.

The tentative methods of sampling and grading rosin are recommended for adoption as standard without revision and it is recommended that the tentative methods of sampling and testing dipentene and pine oil, the methods of testing tall oil, and the definitions of terms relating to tall oil be revised and continued as tentative. New proposed tentative methods of sampling and testing pine tars and pine tar oils, proposed tentative definitions of terms relating to naval stores and related products, and a proposed tentative method of test for acid number of dark-colored rosins are appended. The committee has under consideration a proposed test for unsaponifiable matter in rosin.

Report of Committee D-18 on Soils for Engineering Purposes. E. J. Kilcawley, Acting Chairman.

Records the approval during the year by Committee E-10 on Standards of a new tentative method of test for determining cement content of soil-cement mixtures. Reports completion of a new test for specific gravity of soils and reviews the activities of the committee in considering other methods of testing soils.

Report of Committe D-19 on Water for Industrial Uses. Max Hecht, Chairman.

Tests for total aluminum and aluminum ion, manganese, dissolved oxygen, and silica in industrial waters and a recommended practice for sampling boiler water from stationary boilers, which are being recommended for publication as tentative, are appended to the report. Reference is made to considerations being given to a recommended practice for measuring corrosion in water supplies, based on the National District Heating Association corrosion tester.

Report of Committee D-20 on Plastics. Robert Burns, Chairman.

A procedure for determining ammonia in phenol-formaldehyde molded materials is recommended for publication as tentative. Revisions are recommended in several tentative specifications and methods of test developed by Committee D-20 as well as in the tentative method of conditioning materials before and during testing, method of impact testing and in the tentative recommended practice for molding test specimens. The test for water vapor permeability of plastic sheets and the descriptive nomenclature of objects made from plastics are recommended for adoption as standard. Reference is made to a number of new and revised tentatives accepted by Committee E-10 on Standards on the recommendation of Committee D-20 and to the current activities of the subcommittees including those of the recently organized subcommittee on definitions, nomenclature, and significance of tests.

Papers

A Simplified Method for the Determination of the Specific Gravity of Wood and Plastics. E. George Stern and Paul S. Dear, Virginia Polytechnic Institute.

Using a mercury-balance volumeter, the recommended A.S.T.M. methods for determination of the specific gravity of wood and plastics can be simplified. Complete description is given of the suggested method. Comparison is made of the test data for two materials under observation, yellow poplar and tenite, and obtained according to the various testing methods employed. Several advantages are listed to justify the use of the suggested test method.

Some Factors in the Interpretation of Small-Scale Tests for Fire-Retardant Wood. F. W. Gottschalk, American Lumber and Treating Co.

The special-crib test and the fire-tube test are often used in the research laboratory and at treating plants to determine the degree of fire-retardance of chemically processed lumber. Although a great variety of data can be obtained, the common value to be established by these tests is the percentage of final weight loss.

Because wood is not a homogeneous sub-

stance, such factors as moisture content, density, and chemical content may be responsible for variations in weight. Further investigation is recommended to determine the exact effects of these variables on test results.

Effect of Temperature and Humidity on Mechanical Properties of Molded Cellulose Acetate Plastics. R. F. Hayes, W. E. Welch, T. S. Carswell, and H. K. Nason, Monsanto Chemical Co.

Four molding compound formulations, covering a range of flow gradings were prepared from medium-acetyl (37.7 per cent) and four from high-acetyl (41.0 per cent) cellulose acetate. Test specimens were injection molded from these formulations and physical properties were determined by standard A.S.T.M. procedures. The effect on yield and ultimate strengths in tension, elongation, modulus of elasticity, yield strength in flexure, and impact strength resulting from variations in ambient temperature over the range from −25 C. (−13 F.) to 80 C. (176 F.), and of variation in relative humidity at 25 C. (77 F.) over the range from 0 per cent to 100 per cent were determined, and the results are shown in graphical form. Some data showing the effect of exposure to weather on tensile properties of two of the formulations are presented also. The practical importance of these data is discussed.

Fatigue Tests of a Paper Laminated Plastic. W. N. Findley, University of Illinois.

Two methods of fatigue testing applicable to laminated plastics are described together with the results of the following fatigue tests of a Mitscherlic paper laminate. The data show the effect of different ranges of stress on the fatigue strength in bending and also the effect of different ranges of stress on the fatigue strength in torsion.

In addition, tests on rotating beam type fatigue machines show the effect of speeds of testing from 500 to 15,000 rpm. on the fatigue strength. Results of fatigue tests show the effect of temperature on the fatigue strength.

The effect of a notch on the fatigue strength characteristics of this material is also shown.

Dimensional Stability of Plastics. Robert Burns, Bell Telephone Laboratories, Inc.

This paper is preprinted in this issue of the BULLETIN.

A New Film Thickness Gage. Samuel Lipson, Frankford Arsenal.

An apparatus for measuring the thickness of nonmagnetic films on steel is described and consists essentially of an a-c. energized solenoid containing a soft iron core in its field. Determinations are made by vertically positioning the energized solenoid and core over the specimen, permitting the core to contact the surface of the coating, and measuring the distance through which the solenoid may then be raised before its attraction for the core overcomes that of the magnetized core for the steel basis metal. This distance varies inversely with the thickness of the film. The chief features of the instrument are its portability, rapidity and accuracy of measurement, utilization of standard alternating current power source, and its relative insensitivity to normal voltage variations.

Effect of Dimensions of Specimens Upon the Precision of Strength Data. John Tucker, Jr., National Bureau of Standards.

It has previously been demonstrated in certain tests that the mean strength and the scatter in strength of a group of like specimens will differ from like values obtained in specimens of other dimensions. The paper extends the application to other types of specimens. It also shows how the mean strength and scatter in strength may be predicted for specimens of different dimensions and how dimensions may be advantageously selected. The soundness of the utilization of small test specimens is demonstrated.

The Maximum Stresses Present on the Failure of Specimens of Brittle Materials. John Tucker, Jr., National Bureau of Standards.

It is shown by the statistical theory of strength that stresses much beyond those ordinarily considered as the strength of the material may be present in a portion of specimen under test. It is theoretically demonstrated that the modulus of rupture as usually calculated should be much greater than the tensile strength. Analysis demonstrates that the load at failure of a cement briquet does not have a fixed ratio to the tensile strength of the material. It is also shown that in a concrete cylinder tested in compression with ends restrained the tensile stresses are too small to cause failure in tension.

Analysis of the Effect of Length on the Strength of Compression-Test Specimens. John Tucker, Jr., National Bureau of Standards.

Correction factors have been established in Standard Method C 42-44 to adjust the strengths of shorter specimens to the standard length of twice the diameter.

This paper demonstrates that the variation in strength with change in length is dependent upon several distinct factors, each operative in separate ranges in length. The greatest correction for the shorter specimens depends largely upon the strength of the concrete, and it is fallacious to use one correction factor for a specimen of one length-diameter ratio for all concretes.

It is shown that by the use of smaller diameter specimens a range in length-diameter ratios may be used in which the correction is small.

Students

IT IS not enough that engineering students learn the elements of the sciences that underlie modern technology. They should feel the throb of industrial and civic needs and desire to make a contribution toward their fulfillment. The achievement of this type of coordination between education and life is the basic philosophy of the education venture in which we are engaged. There is no magic of culture in any one subject of instruction or experience, but under the influence of the competent and conscientious, either or both may contribute their full share to the discipline and development of students.—*Ovid W. Eshbach, Dean, Northwestern Technological Institute, in the March "Northwestern Engineer."*

NEW MEMBERS TO MAY 2, 1945

The following 90 members were elected from March 8 to May 2, 1945:

Chicago District

AMERICAN PHENOLIC CORP., R. M. Krueger, Chief, Test Lab., 1830 S. Fifty-fourth Ave., Chicago 50, Ill.

CLEARING MACHINE CORP., A. W. Schultz, Mechanical Engineer, 6499 W. Sixty-fifth St., Chicago 38, Ill.

FACTORY STANDARDS LABORATORY, INC., E. Massey, Vice-President, 416 N. State St., Chicago 10, Ill.

HALLICRAFTERS CO., THE, R. E. Samuelson, Vice-President, Engineering, 2611 Indiana Ave., Chicago 16, Ill.

HARNISCHFEGER CORP., Morris T. Roberts, Chief Metallurgist, 4400 W. National Ave., Milwaukee 14, Wis.

WITCO CHEMICAL CO., E. F. Wagner, Chief Chemist, 6200 W. Fifty-first St., Chicago 38, Ill.

BREWER, CLARENCE T., Engineer, Webster Chicago Corp., 5140 W. North Ave., Chicago 39, Ill.

FISCHER, FRANK O., Chief Field and Service Engineer, Magnetic Analysis Corp., 42–44 Twelfth St., Long Island City, N. Y. For mail: Tinley Park, Ill.

GREENBERG, J. H., Metallurgical Engineer, A. J. Boynton and Co., 310 S. Michigan Ave., Chicago, Ill. For mail: 5131 University, Chicago 15, Ill. [J]*

SCHAIBLE, M. F., Plant Chemist, Libbey-Owens-Ford Glass Co., Ottawa, Ill.

ZUNICK, M. J., Metallurgist and Chemist, General Electric X-Ray Corp., 2012 Jackson Blvd., Chicago 12, Ill.

Cleveland District

ALLIANCE MANUFACTURING CO., E. V. Schneider, Chief Engineer, Lake Park Blvd., Alliance, Ohio.

AMERICAN ANODE, INC., R. V. Yohe, Vice-President, 60 Cherry St., Akron 8, Ohio.

OLIVER CORP., THE, W. A. Silliman, Metallurgist, 19300 Euclid Ave., Cleveland 17, Ohio.

EVANS, CARL E., Foundry Production Superintendent, Sandusky Foundry and Machine Co., Sandusky, Ohio.

Detroit District

ENGINEERING AND TESTING LABORATORIES, INC., J. R. Forrester, Jr., President, 14514 Piedmont Ave., Detroit 23, Mich.

VICKERS, INC., K. G. Monroe, Laboratory Manager, 1400 Oakman Blvd., Detroit 32, Mich.

FOSLER, C. A., Chief Metallurgist, Aluminum Alloys Corp., 7447 St. Aubin, Detroit 11, Mich.

WAGNER, EARL E., Metallurgist, Hoover Ball and Bearing Co., Ann Arbor, Mich.

New York District

CULBERT PIPE AND FITTINGS CO., Edwin W. Thompson, President, 301 West Side Ave., Jersey City 5, N. J.

GRISCOM-RUSSELL CO., THE, O. W. Heimberger, Assistant Chief Engineer, 285 Madison Ave., New York 17, N. Y.

HELLIGE, INC., H. W. Zieler, General Manager, 37-18 Northern Blvd., Long Island City, N. Y.

OAKVILLE COMPANY DIVISION, SCOVILL MANUFACTURING CO., Maurice Henry, Superintendent of Finishing, 26 Main St., Oakville, Conn.

DIENER, FRED P., Chemical Engineer, Universal Atlas Cement Co., 135 E. Forty-second St., New York 17, N. Y.

DITTON, ERB N., Research Director, Gotham Hosiery Co., Inc., 200 Madison Ave., New York, N. Y. For mail: 277 Park Ave., New York, N. Y.

EICHNER, F. L., Manager, Reynolds Metals Co., Metropolitan Ave. and Woodhaven Blvd., Glendale, Long Island, N. Y.

FORBES, GEORGE F., Lieutenant (j.g.) Officer in Charge, Physical Lab., Experimental Dept., Naval Air Station, Lakehurst, N. J.

FRANKLAND, J. M., Supervisor of Structures Test, Chance Vought Aircraft Division of United Aircraft Corp., 550 Main St., Stratford, Conn.

MCKEAN, WALTER A., Chief Chemist, Allied Asphalt and Mineral Corp., Dunellen, N. J. For mail: 555 West Ave., Sewaren, N. J.

MUNYAK, JOHN A., Research Leader, Marco Chemical Co., Sewaren, N. J. For mail: 503 Johnstone St., Perth Amboy, N. J.

NEW YORK TECHNICAL INSTITUTE OF NEW JERSEY, R. G. Dougherty, Principal, 158 Market St., Newark 2, N. J.

REYNOLDS, STANLEY C., Project Manager, W. J. Barney Corp., 101 Park Ave., New York 17, N. Y. For mail: 5 Old Mamaroneck Rd., White Plains, N. Y.

SEXTON, JOSEPH M., Materials Inspection Engineer, The M. W. Kellogg Co., 225 Broadway, New York 7, N. Y. For mail: Apt. D-1, 160 Second Ave., Newark 4, N. J.

STRADAR, GEORGE F., Materials Engineer, Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y.

WEISBERG, HARRY, Chemist, E. I. du Pont de Nemours and Co., Inc., Grasselli, N. J. For mail: 155 E. Fifty-second St., Brooklyn 3, N. Y. [J]*

Northern California District

HEDREEN, CARL A., Manager, Ocean Industries Laboratory, Box 631, South San Francisco, Calif.

Philadelphia District

BAKER CHEMICAL CO., J. T., J. R. Stevens, Director of Research, Phillipsburg, N. J.

MOREHOUSE MACHINE CO., H. E. Zumbrun, President, 233 W. Market St., York, Pa.

ALEXANDER, JULIAN, In Charge of Service Labs., Houdry Process Corp. of Pennsylvania, Box 427, Marcus Hook, Pa.

BOUNDS, ARDREY M., Chief Metallurgist, Superior Tube Co., Norristown, Pa. For mail: 7121 Cresheim Rd., Philadelphia 19, Pa.

GETZ, JOHN H., JR., Architect, Atlantic Refining Co., 260 S. Broad St., Philadelphia 2, Pa. For mail: 7008 Limekiln Pike, Philadelphia 38, Pa.

Pittsburgh District

PRISMO SAFETY CORP., A. E. Keeley, Chief Engineer, 301 Penn St., Huntingdon, Pa.

STANDARD STEEL SPRING CO., Frank R. Keller, Superintendent, Coraopolis, Pa.

HEBERLEIN, GUSTAVE E., Chief Engineer, Railway and Industrial Engineering Co., Box 98, Greensburg, Pa.

KLINE, C. BENTON, Chief Specification Examiner, Alloy, Carnegie-Illinois Steel Corp., 434 Fifth Ave., Pittsburgh 30, Pa.

STROBEL, CHARLES K., Assistant Director of Research, Robertshaw Thermostat Co., 1201 Washington Blvd., Pittsburgh 6, Pa

St. Louis District

NOOTER BOILER WORKS CO., JOHN, Arthur Schwarz, Engineer, 1401 S. Second St., St. Louis 4, Mo.

LARKIN, J. J., JR., Executive Vice-President, 6200 Maple Ave., St. Louis 14, Mo.

LOVE, M. P. L., Research Director, Shell Oil Co., Inc., Box 262, Wood River, Ill.

Southern California District

PLASTIC AND RUBBER PRODUCTS CO., Thomas B. Keenan, Chief Chemist, 2100 Hyde Park Blvd., Los Angeles 44, Calif.

STANDARD FELT CO., DIVISION OF HUNTINGTON LANE AND IMPROVEMENT CO., Herman G. Berglund, Eastern District Manager, • 29-115 S. Palm Ave., Alhambra, Calif.

SAVAGE, RICHARD C., Chief Chemist, Old Colony Paint and Chemical Co., 620 Lamar St., Los Angeles 31, Calif.

Western New York-Ontario District

PIERCE & STEVENS, INC., D. E. Ellis, Technical Director, 710 Ohio St., Buffalo 3, N. Y.

U. S. and Possessions

OTHER THAN A.S.T.M. DISTRICTS

ATLANTIC REFINING CO., THE, J. H. Sullivan, Senior Laboratory Engineer, Box 2819, Dallas 1, Tex.

CARLISLE TIRE AND RUBBER CO., L. J. Dete, Chief Chemist, Carlisle, Pa.

HODGMAN RUBBER CO., Joseph L. Haas, Technical Director, Framingham, Mass.

MILLETT CORP., Lloyd W. Carpenter, Chemist, Gilman, Vt.

PHALO PLASTICS CORP., Albert N. Averill, Sales Engineer, 25 Foster St., Worcester 8, Mass.

PONTIAC REFINING CORP., Edwin Singer, President, Box 1581, Corpus Christi, Tex.

STEIN LABORATORIES, FRED, E. A. Moore, Vice-President, 121 N. Fourth St., Atchison, Kans.

BALSTER, WILMER J., Research and Development Engineer, Military Planning Division, Office of the Quartermaster General, U. S. Army, Temporary Bldg. A, Second and T Sts., Washington, D. C. For mail: 2840 S. Abingdon Dr., Arlington, Va.

CALKINS, LOUIS A., Chief Engineer, Valvoline Oil Co., Fifth and Butler Sts., Cincinnati, Ohio. For mail: 318 Atlantic Ave., Franklin, Pa.

COSTA, ROBERTO MILLER F., Technical Adviser, Brazilian Embassy, 3007 Whitehaven St., N. W., Washington 9, D. C. [J]*

GRAEBNER, W. H., Director, Technical Service, Marathon Corp., Menasha, Wis.

GRAY, J. G., Central Research Lab., Trinity Portland Cement Co., Box 152, Houston 1, Tex.

HARRISON, W. N., Chief, Enameled Metals Section, National Bureau of Standards, Washington 25, D. C.

LUKENS, ALAN R., President, Pigment Research Laboratories, 11 Windsor St., Cambridge, Mass.

RUDGERS, ANTHONY J., Chief, Federal Specifications Division, Procurement Division, U. S. Treasury Dept., Seventh and D Sts., S. W., Washington 25, D. C. For mail: 304 S. Ivy St., Arlington, Va.

UNIVERSITY OF WASHINGTON, DEPARTMENT OF CIVIL ENGINEERING, R. G. Hennes, Associate Professor, 316 Guggenheim Hall, Seattle 5, Wash.

UNIVERSITY OF WICHITA LIBRARY, Roy W. Elliott, Comptroller, Wichita, Kans.

VASSAR, THOMAS E., Eureka Specialty Printing Co., 530 Electric St., Scranton 9, Pa.

WERKENTHIN, THEODORE A., Principal Materials Engineer, U. S. Navy, Bureau of Ships, Washington, D. C. For mail: 3601 Second St., South, Arlington, Va.

Other than U. S. Possessions

BRITISH AMERICAN OIL CO., LTD., THE, Carlyle D. Read, Chief Process Engineer, 703 Royal Bank Bldg., Toronto, Ont., Canada.

COMPAÑIA ANONIMA VENEZOLANA DE CEMENTOS, Henrique Thielen T., General Manager, Apartado 332, Caracas, Venezuela.

ROGERS ELECTRONIC TUBES, LTD., W. H. Kohl, Chief Engineer, 622 Fleet St., Toronto, Ont., Canada.

STEEL SALES CO. OF AFRICA (PTY.), LTD. Jack Ramsbottom, Manager, Special Steels Dept., Escom House, Rissik St., Johannesburg, South Africa.

AUCKLAND UNIVERSITY COLLEGE, SCHOOL OF ARCHITECTURE, Princes St., Auckland C. 1, New Zealand.

AUSTRALIA, CHIEF PURCHASING OFFICER, MINISTRY OF MUNITIONS, 390 Little Collins St., Melbourne, Victoria, Australia.

AUSTRALIA, COMMONWEALTH ANALYST, COMMONWEALTH LABORATORY, Flinders Lane, Melbourne, Victoria, Australia.

AUSTRALIA, DIVISION OF AERONAUTICS, CSIR, Chief, Lorimer St., Fishermen's Bend, Victoria, Australia.

BAMPFIELD, A. E., Chief Chemist, Australia Cement, Ltd., Geelong, Victoria, Australia.

BELLERBY, WILLIAM A., Analyst and Tester of Textile Materials, Lister and Co., Ltd., Manningham Mills, Bradford, Yorks, England. For mail: 3 Oak Ave., Manningham, Bradford, Yorks, England.

BRITISH MINISTRY OF WORKS, The Librarian, Lambeth Bridge House, London, S.E. 1, England.

BROWN, ROBERT JAMES, Chief Chemist and Metallurgist, Morris Motors, Ltd., Engines Branch, Courthouse Green, Coventry, England.

CLARKE, D. H., James Booth and Co., Ltd., Argyle Street Works, Nechells, Birmingham 7, England.

DEW, SIDNEY BERNARD, Chief Metallurgist (Non-Ferrous), Wellworthy Piston Rings, Ltd., 89 Blackfriars Rd., London, S.E. 1, England.

KANE, J., Chief Chemist, Dominion Arsenal, St. Malo, Quebec, P. Q., Canada.

ROWBOTHAM, N., Chief Engineer, The Bristol Aeroplane Co., Ltd., Engine Division, Bristol, England.

SMITH, CHRISTOPHER, Chief Metallurgist, James Booth and Co., Ltd., Argyle Street Works, Nechells, Birmingham 7, England.

WILES, JOHN R., Chief Metallurgist, A. C. Wickman, Ltd., Coventry, England.

* [J]—Denotes Junior Member.

Personals . . .

. . . News items concerning the activities of our members will be welcomed for inclusion in this column.

G. K. SCRIBNER, President, Boonton Molding Co., Boonton, N. J., has been appointed chairman of a Plastics Advisory Committee organized by Princeton University in connection with its new plastics program. Other A.S.T.M. members are serving with him. The program, a joint one sponsored by the School of Engineering, is a cooperative enterprise representing the mechanical, chemical, and electrical engineering departments as well as the departments of chemistry and physics. Its primary objectives are instruction and research in the application, fabrication, processing, and basic properties of plastics as engineering materials.

R. F. WEBER, committee representative of International Harvester Co., has been elected national president of a new Industrial Packaging Engineers Association of America. The group comprises active members who are packing officials, and associate members who are packaging materials sales agents with corporate members also participating. This new group is another of the numerous recognitions of the important place that packaging engineers have assumed in the war years.

This column, normally reserved for members, and sometimes notes on committee people who are not members, occasionally breaks its precedent, and we are pleased to do so noting a record of service by (Mrs.) Winifred E Stegler, secretary for many years to Dr. R. P. Anderson, formerly secretary of Committee D-2, and now serving in a similar capacity for D. V. Stroop Secretary of D-2 and Director, Department of Engineering, American Petroleum Institute. In August Mrs. Stegler will have been the "behind the scenes secretary" of Committee D-2 for twenty-two years.

HAROLD H. MORGAN, Past-President of the Society and former Chairman of Committee A-1 on Steel, has been elected Vice-Presdent and Chief Engineer of the Robert W. Hunt Co. Mr. Morgan was formerly Chief Engineer. At the same time, JAMES C. OGDEN, formerly President, has been made Chairman of the Board and William L. Cooper, formerly Vice-President, is the new President. Other officers were reelected, including FRED M. RANDLETT, Vice-President and General Manager. Also, DAVID W. McNAUGHER, JR., continues as Vice-President and Assistant Treasurer.

Two men who have been active in A.S.T.M. work have had their distinctive efforts in behalf of the Western Society of Engineers rewarded by being unanimously elected to honorary life membership—namely, THEODORE L. CONDRON and ALBERT REICHMANN. Mr. Condron, retired consulting engineer, has been a member of A.S.T.M. continuously since 1900 and thus in 1940 was awarded his Forty-Year Certificate. Mr. Reichmann was an active member of A.S.T.M. for many years up to his retirement in 1938 when he was Vice-President of American Bridge Co.

ALEXANDER FOSTER, JR., Vice-President, Warner Co., Philadelphia, Pa., has been elected President of the National Ready Mixed Concrete Association. He has been active in this group and in others concerned with the field of concrete and concrete aggregates for many years.

GUSTAF SODERBERG, formerly Head Industrial Specialist, Conservation Officers Staff, Office of Operations; and Vice-Chairman, War Production Board, Washington, D. C., is now Consulting Engineer, Graham, Crowley and Associates, 473 York Road, Jenkintown, Pa.

H. S. MATTIMORE is "on the move again," he says. He is now located at Public Works Department, Naval Operating Base, Terminal Island (San Pedro), Calif., with mailing address at 1617 Weymouth Ave., Apt. "C," San Pedro, Calif.

ROBERT J. MOORE, who was Manager, Development Laboratories, Bakelite Corp., Bloomfield, N. J., has been appointed Technical Co-ordinator and is located in the New York executive offices of the corporation. Dr. Moore was the speaker at the Chicago Section meeting of the American Chemical Society celebrating its fiftieth anniversary, held on March 15, his subject being "Synthetic Resin Plastics."

M. M. CLARK, who is now Metallurgical Engineer, Climax Molybdenum Co., Canton, Ohio, was Manager, Bar and Semi-Finished Bureau, Metallurgical Division, Carnegie-Illinois Steel Corp., Chicago, Ill.

DANIEL F. SMITH is now located with the Southport Petroleum Co. of Delaware in Texas City, Tex.

BATTELLE MEMORIAL INSTITUTE, Columbus, Ohio, has announced the appointment to its staff of J. Robert Van Pelt, formerly Technical Director, The Museum of Science and Industry, Chicago, Ill., who will assume responsibility for an expanded program of Research Education.

TRACY C. JARRETT, Chief Metallurgist, American Hammered Piston Ring Division, Koppers Co., Inc., Baltimore, Md., has been appointed to the technical committee of the Gray Iron Founders' Society by the trade group's president, Walter L. Seelbach of Cleveland. Dr. Jarrett, who received his degree in metallurgy from Harvard Engineering School in 1936, was Assistant Chief Metallurgist of the American Optical Co. before joining Koppers.

CECIL W. ARMSTRONG, formerly Chief Research Engineer, Plastics Division, Continental Can Co., Inc., Chicago, Ill., is now General Manager, Armstrong Plastics Co., Chicago, Ill.

JOHN L. EVERHART is now Research Engineer, Non-ferrous Division, Battelle Memorial Institute, Columbus 1, Ohio. He was connected with the National Bureau of Standards, Washington, D. C., as Engineer.

A. F. GILL is now connected with J. T. Donald and Co., Ltd., 1181 Guy St., Montreal, Canada. He was formerly with Beardmore and Co., Ltd., Acton, Ont., Canada.

J. G. BENNETT, who was Director, The British Coal Utilisation Research Association, Experimental Station, London, S.W. 6, England, is now with Delanium, Ltd., London, W. 1, England.

E. W. ROMIG, formerly Chief Engineer of the Cleveland Plant, has been appointed Vice-President in Charge of the Cleveland District, Claud S. Gordon Co., Chicago, Ill. Mr. Romig joined the organization in 1938.

NORBERT K. KOEBEL, formerly Director of Research, has been appointed Manager of Sales for Lindberg Engineering Co., Chicago, Ill. Since October, 1940, he has been Director of Research at Lindberg in which capacity he will continue to serve.

ALEXANDER SCHWARCMAN, Research Chemist, Spencer, Kellogg and Sons, Inc., Buffalo, N. Y., was recently awarded the Jacob F. Schoellkopf Medal for 1945 by the Jury of Award of the Western New York Section of the American Chemical Society, for his original and entirely new concepts in chemical processing of vegetable oils.

Two A.S.T.M. members have been made the heads of two new sections recently created in the Development and Research Division of the International Nickel Co., Inc., New York, N. Y., as follows: O. B. J. FRASER will head the Industrial Chemicals Section, and F. L. LaQUE the Corrosion Engineering Section. Mr. Fraser is Director of Technical Service on Mill Production, and Mr. LaQue, Metallurgist of the Development and Research Division.

JOHAN BJORKSTEN, owner of the Bjorksten Laboratories, Chicago, Ill., has advised of new and larger quarters at their address, 185 Wabash Ave. Dr. Bjorksten still retains his partnership in the A-B-C Packaging Machine Co.

L. K. HERNDON, Secretary of Committee C-7 on Lime, has been made Associate Professor of Chemical Engineering, The Ohio State University, Columbus, Ohio. He was formerly Assistant Professor.

W. S. JAMES, formerly Chief Engineer of The Studebaker Corp., South Bend, Ind., and a leading authority in the materials field, who has been concerned with various phases of A.S.T.M. work, including those on Committee D-2 on Petroleum Products and Lubricants, is now affiliated with the Engineering Laboratory of Ford Motor Co. in Dearborn, Mich.

ROY W. CRUM, long-time member of the Society (since 1911), Director of the Highway Research Board, National Research Council, Washington, D. C., who has been active in A.S.T.M. work for many years, particularly in the work of Committee C-9 on Concrete and Concrete Aggregates, of which he is a past-chairman, has prepared an article in the April issue of *American Highways*, organ of the American Association of State Highway Officials, describing in some detail the Highway Research Board in which he points out that correlation and dissemination of research information from widely scattered sources dealing with highway design and construction is one of the important contributions of the Board.

The many friends and associates in the Society of DR. H. S. RAWDON, Chief, Division of Metallurgy, National Bureau of Standards, Washington, D. C., will be interested to know that he is making progress from a recent operation and is expected to be about in a few weeks.

CHESTER HACKING, General Superintendent, William H. Haskell Manufacturing Co., Pawtucket, R. I., and chairman of the Steel Committee's Section on Bolting and Nuts for High-Temperature Service, is back on active duty after a rather long illness. His company, celebrating this year 125 years of service, is a leading manufacturer of alloy steel, stainless steel, and other types of bolting and nuts. The company traces its activities from Colonel Stephen Jenks who began to manufacture bolts in 1820.

M. W. LOVING, for many years Secretary-Treasurer of the American Concrete Pipe Association, and representative of this group in the Society, is relinquishing his administrative duties with the Association, but is continuing as a Consultant. This change will permit Mr. Loving to devote more time to his consulting work. He has been quite active in A.S.T.M. technical work and has been secretary of Committee C-13 on Concrete Pipe for many years.

ZAY JEFFRIES, Vice-President and General Manager, Chemical Department, General Electric Co., Pittsfield, Mass., spoke as first annual medal lecturer of the Stevens Institute of Technology powder

metallurgy laboratory on March 7 at the Institute, Hoboken, N. J. Dr. Jeffries also received the Clamer Medal for achievement in metallurgy awarded by the Franklin Institute.

Two A.S.T.M. members have been nominated for office in the Milwaukee Chapter of the American Society of Metals: J. T. JARMAN, General Superintendent, Allis-Chalmers Manufacturing Co., Milwaukee, Wis., *Chairman;* and E. J. WELLAUER, Supervisor of Research and Metallurgy, Falk Corp., Milwaukee, Wis., *Vice-Chairman.*

J. H. WALKER, for some time Superintendent of the Central Heating Department and Engineer Assistant to General Manager, The Detroit Edison Co., Detroit, Mich., has been elected a Vice-President of the company, his work in the Central Heating Department being assigned to E. E. Dubry. Mr. Walker has been very active in the work of Committee C-16 on Thermal Insulating Materials and is Honorary Chairman of the Committee.

FELIX EDGAR WORMSER, Secretary and Treasurer, Lead Industries Association, New York, N. Y., has also been elected Secretary and Treasurer of the Metal Powder Association.

ROBERT B. HARPER, Vice-President, The Peoples Gas Light and Coke Co., Chicago 3, Ill., has been elected second vice-president of the Western Society of Engineers.

HAROLD DEWITT SMITH, Treasurer and Textile Technologist, The A. M. Tenney Associates, Inc., New York, N. Y., who gave the 1944 A.S.T.M. Marburg Lecture which is now in course of publication will be the new president of the Textile Research Institute. The current president, F. S. Blanchard, and the first vice-president, DOUGLAS G. WOOLF, have submitted their resignations, effective June 30. Both Messrs. Blanchard and Woolf will continue as directors. The official organ of the Institute is to be extended as a scientific journal with F. BONET, Director, Standards Department, American Viscose Corp., Earl Constantine, and R. W. VOSE, Director of Research, Chicopee Manufacturing Corp. studying the necessary changes.

ROY CROSS, President, Kansas City Testing Laboratory, Kansas City, Mo., is a member of the Board of Governors of the new Midwest Research Institute which held its annual meeting in February bringing together many leaders in science, business and industry from the six adjoining states. Mr. Cross, one of the founders of the Institute, presided at the afternoon panel discussion covering research opportunities in agriculture, minerals, and petroleum and on the industrial outlook for the Midwest.

H. R. MAUERSBERGER, Technical Editor for Rayon Publishing Corp., announces the formation and organization of a new book-publishing concern, known as "Textile Book Publishers, Inc.," 303 5th Ave., New York 16, N. Y. This new corporation will publish and offer distinctive and authoritative Guides, Manuals, Reference and Textbooks on Textile and related subjects of general, technical, and scientific character.

J. J. DUFFY, JR., formerly Service Engineer, The Pennsylvania Salt Manufacturing Co., Philadelphia, Pa., has been appointed Assistant Manager of Sales.

H. S. FREYNIK has been named Chief Metallurgist of the Riverside Metal Co., Riverside, N. J.

News Notes on Organizations Furnishing Testing and Scientific Equipment and Testing Services

EDITOR'S NOTE.—From time to time this column will include notes on items that would be of interest to the members concerning activities of companies which manufacture or distribute testing and scientific equipment and news on professional testing laboratories.

Morehouse Machine Co., York, Pa., whose company membership continues the contact with A.S.T.M. by the late W. S. Morehouse, has elected officers as follows: H. E. Zumbrun, President; F. W. Hoffmeyer, Vice-President; L. N. Roth, Secretary and Treasurer. The company at its plant in York is continuing its activity as toolmakers, machinists, and manufacturers of proving rings for checking hardness, universal, and other testing machines.

NECROLOGY

(Dates of death are given when available)

H. N. BOETCHER, Assistant to Superintendent, Power Production Stations, Consolidated Gas Electric Light and Power Co. of Baltimore, Md., represented the Sustaining Membership of his company in the Society. He had been actively concerned with the work of Committee A-1 on Steel for a number of years. In recent weeks he had carried out for the committee a most important project involving a new specification which would cover piping materials for service at elevated temperatures that would not tend to graphitize. An authority on corrosion and on welding, he had been with his company since 1925, engaged primarily with the construction, design, and operation of steam electric generating plants. His many friends and associates in A.S.T.M. sincerely regret his passing at the age of 47 on April 19.

GEORGE TERRY HORTON, President, Chicago Bridge and Iron Co., Chicago, Ill. A Past-President of the American Welding Society and a member of the Board of Trustees at Rensselaer Polytechnic Institute where he had established an extensive welding laboratory, Mr. Horton was also interested in A.S.T.M. work, serving as the representative of a Sustaining Membership. He was killed in an automobile accident in Chicago on March 19.

OSCAR A. CHERRY, Research Chemist, Nubian Paint and Varnish Co., Division of The Glidden Co., Chicago, Ill. Member since 1941. Mr. Cherry, at the time of his death, was serving as one of the representatives of The Glidden Co. Paint Divisions in its membership on Committee D-1 on Paint, Varnish, Lacquer, and Related Products. (January 13.)

GEORGE L. ROBERTS, Chief Chemist, United Carbon Co., Inc., Charleston, W. Va. Mr. Roberts represented his company in its membership on Committee D-11 on Rubber and Rubber-Like Materials and on subcommittees on physical testing, on chemical analysis, on life tests, and on flexing tests.

H. W. WRIGLEY, Laboratory Supervisor, Westinghouse Electric and Manufacturing Co., Cleveland, Ohio. Member since 1941. Mr. Wrigley was one of the representatives of Westinghouse in its membership on Committee D-20 on Plastics and the subcommittee on optical properties. (January 26.)

WILLIAM BROKAW BAMFORD, Architect and Consulting Engineer, Belmar, N. J. Member since 1913. (April 10.)

KARL A. LINDNER, General Manager, Atlantic Coast Refineries, and Research, American Smelting and Refining Co., Barber, N. J., member since 1932. Mr. Lindner represented his company in its membership on Committee B-2 on Non-Ferrous Metals and Alloys, and subcommittees on refined copper, on refined lead, tin, antimony and bismuth. (March 3.)

While he was not a member of A.S.T.M., we record with regret the death of ALEXIS SOMMARIPA, formerly with E. I. du Pont de Nemours & Co., Inc., and at that time very active in the work of A.S.T.M. Committee D-13 on Textile Materials. He was killed in Germany on March 28 while serving as a civilian member of the psychological warfare branch of the Army. He had been awarded the Bronze Star for his services.

Alfred Victor deForest

1888–1945

One of the country's outstanding scientists, Alfred Victor deForest, who died suddenly on April 4, had been active in A.S.T.M. work for many years and had prepared numerous technical papers one of which earned for him in 1927 the award of the Charles B. Dudley Medal as an outstanding contribution to research. Chairman of the Board of Directors of Magnaflux Corp., he was also Professor of Mechanical Engineering at Massachusetts Institute of Technology from which he had graduated in 1911. Successively he was Instructor at Princeton University, was with the Remington Arms Co., and Research Engineer at the American Chain Co., in the latter capacity from 1918 to 1930. He had served as consulting engineer to many organizations, particularly on strength and fatigue of metals, and on methods of inspection. He had earned many honors including the Franklin Institute Longstreth Medal for his work in magnetic particle testing. He was a Henry Marion Howe Lecturer of the A.I.M.E.

In the Society he had served on several committees: the former Committee A-8 on Magnetic Analysis and the Research Committee on Fatigue of Metals among others. A rather prolific writer, one of his latest contributions with C. E. Betz was a paper in the Symposium on Magnetic Particle Testing held by A.S.T.M. in February, 1945. His family, Mrs.

deForest and two children, a son, Taber, and a daughter, Judith, survives.

Carl Foster Hanson

1884–1945

In the death on April 27 of Carl Foster Hanson the Society loses another of its long-time members who had done much to advance A.S.T.M. work particularly in the field of electrical insulating materials where he was an authority on the use of insulating varnishes and related materials. The Technical Director of Irvington Varnish and Insulator Co., Irvington, N. J., since 1930, he previously had been with R. T. Vanderbilt Co., was Research Director of Habirshaw Cable and Wire Co. for some ten years, and prior to that was with the National Bureau of Standards. A native of Kansas, he had graduated from the University of Kansas. Mr. Hanson had been active in A.S.T.M. committee work since 1927 at which time his affiliation with Committee D-9 on Electrical Insulating Materials began. A member of many of its subcommittees, he was chairman of Subcommittee I on Insulating Varnishes, Paints and Lacquers, and was a member of the Advisory Committee. Also he had periods of service as a member of Committee D-2 on Petroleum Products and Lubricants and Committee D-13 on Textile Materials.

Respected and admired by all who knew him—a wide circle of people in A.S.T.M.—his death is a distinct loss to the Society. With this note the Society pays tribute to his activities in its behalf, and extends its sympathy to his family.

William Reuben Webster

1868–1945

The sudden death from a heart attack in the Bellevue-Stratford Hotel, Philadelphia, a short distance from A.S.T.M. Headquarters, of William R. Webster, Chairman of the Board of the Bridgeport Brass Co., brings to a close a most interesting career in the non-ferrous metals industry. Mr. Webster died on April 28 while visiting his wife who had been under treatment at Graduate Hospital. He had been very active in the development of the brass industry and participated in the work of numerous societies, including A.S.T.M. where he had served on several of the non-ferrous metal committees for a great many years. He was a member of the Executive Committee from 1935 to 1937. He had been particularly active on the Society's Committees B-2 on Non-Ferrous Metals and Alloys, B-3 on Corrosion of Non-Ferrous Metals and Alloys, and B-5 on Copper and Copper Alloys, Cast and Wrought, serving as a member of each for many years. A graduate of Cornell University in 1890 he was associated with Westinghouse Church, Kerr and Co., Bridgeport Copper Co., and from 1897 was successively Foreman, General Superintendent, Vice-President, and Chairman of the Board of Bridgeport Brass Co. He was very active in civic enterprises in Bridgeport and his membership in technical societies included many of the leading groups. He was a past-chairman of the A.S.M.E. Research Committee. His membership in A.S.T.M. dating from 1909 placed him with those who participated in the laying of the groundwork for outstanding technical work carried out by A.S.T.M. in the brass and non-ferrous metals fields. In his death the Society loses a loyal member who for thirty-seven years had contributed much to its work. In addition to Mrs. Webster, two children survive—Eleanor and William Reuben, Jr.

Frederick Addison Harvey

1882–1945

Director of Research, Harbison-Walker Refractories Co., Pittsburgh, Pa., Dr. Harvey was an outstanding authority in the field of refractories, and had been a most active member of A.S.T.M. for over 25 years. Like many technical people in the Society, his interests were confined primarily to one field, but in this field he contributed greatly to advancement of the Society's work in development of specifications and particularly standard tests for refractories, and promoting knowledge of the properties of these materials. He was also intensely interested in promoting the use of standards and cooperated closely with the Fellowship of the American Refractories Institute at Mellon in issuing a translation of A.S.T.M. tests which were published in Spanish. A graduate of universities in this country and abroad, he was for several years a professor at Syracuse University, later associated with the Semet-Solvay Co., then with U. S. Refractories Corp., and has been with Harbison-Walker since 1926, as Director of Research since 1932. Dr. Harvey wrote many technical papers, reports, and articles, and held numerous patents. The Society's Committee C-8 on Refractories, where he had served on several subcommittees, and the Advisory group, will indeed miss his active, constant support. Mrs. Harvey and two married daughters survive. (Date of death, April 27.)

Charles Hollister Davis

1886–1945

With profound regret we record, just as this BULLETIN nears press, the death of C. H. Davis, very active member of the Society for many years and one who contributed greatly to the Society's work, particularly in the field of non-ferrous metals and alloys, where he was an outstanding authority. Assistant Technical Manager of the American Brass Co., he had for several years until 1944 served as Secretary of Committee B-5 on Copper and Copper Alloys, Cast and Wrought, and participated in the work of several other committees. In 1930 he was co-winner with W. A. Straw and J. R. Townsend of the Charles B. Dudley Medal for the outstanding paper on "Physical Properties and Methods of Test for Some Sheet Non-Ferrous Metals." A more detailed statement on Mr. Davis' activities will appear in the August BULLETIN.

Professional Development

THE twelfth annual report of the Engineers' Council for Professional Development includes much information and many data that will be of interest to every engineer whether civil, mechanical, testing, or whatever his interests. There is a list of the accredited engineering curricula, a reading list for junior engineers, and information on engineering ethics, employment conditions, and reports of the constituent professional organizations. Also noted are various publications of interest in this field. Copies of the Report are available from the Secretary of ECPD, 29 West 39th St., New York 18, N. Y., at 25 cents each.